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SELECTIONS FROM THE RECORDS

OF THE OFFICE OF THE

FINANCIAL COMMISSIONER, PUNJAB.

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SELECTIONS FROM THE RECORDS

OF THE

FINANCIAL COMMISSIONER'S OFFICE, No. 31.

No. LIX.—CORRESPONDENCE RELATING TO THE CONSTRUCTION OF WELLS FOR IRRIGATION.

Papers Published by Government of N. W. P. and Oudh.

No. of 1883, dated Cawnpore, the 27th May 1883, from W. C. Benett, Esq. Director Department of Agriculture and Commerce, North-Western Provinces to the Secretary, Board of Revenue, North-Western Provinces.

I HAVE the honor to submit—

(1) A note by Captain Clibborn, Executive Engineer, on the results of the enquiry into the general subject of the construction of wells, for which he was specially deputed last year.

(2) A note by Mr. W. J. Wilson, Assistant Engineer, on deputation with this department, on the construction of wells on the Awa estate.

2. As this appears to be a convenient occasion to review the origin and results of the action taken by Government in the matter of well building, I have had bound up with the above reports, a note on the experimental wells in Moradabad, giving their history to the end of July 1882, when the officer in special charge of them was removed. It has not been thought necessary to give any account of the Cawnpore wells, as that experiment was closed and reported on more than two years ago. Since the date of the papers now submitted, further action has been taken. Captain Clibborn was deputed early in the cold weather to make a special report on the condition of well construction on Rája Shambhu Narain Singh's estate in Gházipur, and Mr. Wilson has not only made further progress with the Awa wells, but has visited several districts to advise with Collectors on irrigation projects, and is now commencing a new experiment at Khairagarh in the Agra district.

3. The subject was forced on the attention of Government by the famine of 1877-78. The experience of several years has shown that the protection of any considerable areas by well irrigation could not be looked for as the result of advances under the existing Takávi Act, and it became necesssary to decide how the action of Government could be made more direct, and more effective. After an extended enquiry, the Board of Revenue drafted a Bill, the main object of which was contained in its third section, which provided that, whenever it might be proved to the satisfaction of the Local Government, that in any tract of country or in any mahál, the construction of wells for irrigation was required to protect the area from famine or the effects of drought, and that such wells would not otherwise be constructed, the Local Government might order the construction of wells in such number, and of such description, as might be deemed necessary.

4. In a note on the proposed scheme by Mr. Buck, who was then Director of Agriculture and Commerce, it was pointed out that it was first necessary to ascertain whether the construction of wells in any tract was (1) feasible; (2) remunerative: and it was suggested that certain figures which he had brought forward should be tested by experiments, the trial of which should be made by the Agricultural Department, one of whose main duties was the study both of well construction and of water lifts. It was further urged that the special difficulties of the undertaking could not be met without a combination of revenue knowledge with engineering skill, and that success could not be expected from the unassisted agency of the ordinary district staff.

5. In its order reviewing the voluminous notes and suggestions which had been put before it, Government remarked on the insufficiency of the data, and the uncertainty with which the whole subject was involved, and expressed a fear, that hasty action for the general construction of wells would lead to nothing but disappointment and disaster. It was thought that there was no section of agricultural operations which depended upon more numerous or more intricate conditions, both above the ground and under the ground, than well irrigation; and that before any compulsory measures for the construction of wells by the State could be adopted, it would be necessary to make detailed enquiries in every tract to which operations were to be extended. As a preliminary measure, two tracts were to be chosen in different parts of the Province, in which there were *primâ facie* reasons for believing that wells could be constructed at a reasonable cost with advantage to the agricultural community; and a special officer was to be deputed to each to find out in each village whether or no wells could be made. If it was found that they could, he was to receive special engineering assistance, and the whole work was to be under the general superintendence of the Provincial Department of Agriculture, which was to assist with its advice the officers engaged, and review the progress of their work for the information of Government.

6. These views were put into effect by the institution of experiments under Mr. Wright at Cawnpore and Mr. Smeaton at Moradabad. In the autumn of 1881, it was thought possible that sufficient experience had been gained to warrant the expenditure of a large sum of public money, and Captain Clibborn was deputed to make a tour of the Provinces, and report the localities in which wells could be most profitably constructed by the State, and the conditions of their construction. Some years ago the Board of Revenue authorized Mr. Crooke, the manager of the large Court of Wards Estate of Awa, to invest three lakhs of its savings on wells. The work was entrusted to Mr. Wilson, and has since been conducted under his supervision. It remains to be seen what lessons have been taught by the experience of the last four years, on the general question of well building, and what further action Government can take in the matter.

7. The first result of these enquiries is to discredit the distinction which used to be drawn between spring and percolation water. The President of the Famine Commission says that "the putting down of a borer, and coming on water, proves nothing. It may be a spring or a trickle from percolation." But it now appears to be certain that there is nothing resembling an artesian basin in these Provinces, at any rate at a depth to which it is possible to sink a cylinder well.* There is no continuous impervious stratum separating the water which comes in from the bottom from what would percolate through the sides of a well; and therefore no true spring. The water at every depth of a water-bearing stratum is connected, and the same in origin. If it were otherwise, and the water were drawn from different sources, there would be no connexion of cause and effect between the water outside and the water inside of the cylinder of a so-called spring well. But it is a known fact, that the discharge into a well is regulated by the height of water outside it, and that the level of the former is determined by its tendency to reach the level of the latter. The only true spring is not a natural but an artificial one, and is first formed when the cylinder of the well interposes an impervious barrier to the water outside it.

8. The main difficulty, then, in well construction is not the discovery of water. The water level is known locally all over the Provinces, and the information is being collected on a map, which it is hoped may shortly be published by the Department. The sub-soil water supply in the greater part of the Provinces is practically inexhaustible, and in ninety-nine cases out of a hundred, if a well fails, it is because the locality selected will not support the weight of the cylinder. The conditions under which a well is stable are well described in Captain Clibborn's note. The resistance of sand to the passage of water, will cause a hollow to be formed under every well, and the contents of this hollow will be carried in with the water, till the discharge within the

* There may be local exceptions, as at Benares where phenomena resembling an artesian discharge have been noticed but none have been proved; and if they exist, they are too rare to affect the general problem of well sinking.

hollow has been distributed over a surface which is sufficiently large to reduce the velocity at any given point to such a degree, as will enable the sand to deliver the water without being disturbed. This point was illustrated by some experiments made by Captain Clibborn with a half well sunk in a box full of sand, and fitted with a glass face. As long as there was only little water in the box, and very slow discharge into the bottom of the well, the water came up quite clear, and without disturbing the sand. But directly the velocity of the water was increased, by adding to the head in the box, it brought up large volumes of sand with it into the well. What the area of this hollow should be depends on the amount of water drawn within a given time from the well, and on the size of the particles of which the sand is composed, as fine sand offers more resistance to water than coarse. But in the case of wells to be used for irrigation purposes, from which a large and constant supply is expected, its diameter will always be much greater than the diameter of the curb of the well. The consequence is that in a very short time the cylinder, unless it has some other support than the sand underneath it, slips into the hollow which has been formed by the water drawn into the well. This necessary support is given by the clay stratum, known as the mota, which must interpose between the cylinder and the hollow formed by the water discharge, in order that a well may be stable.

9. All that is known about this clay stratum is that it is not continuous, and that its occurrence in one place is no indication that it will occur in another, perhaps only a field off. The extreme capriciousness and uncertainty of its distribution, is illustrated in every locality where trial borings or experimental wells have been made, and may be seen on a small scale in the extraordinary diversities of the sub-soil strata within the space of a few hundred square yards which were mapped by Mr. Wilson, and published with last year's Administration Report.

10. The first problem in well construction is to discover this indispensable stratum to rest the well on, and whether it is thick enough to bear the weight which will be put upon it. How fully alive to this fact the natives of these Provinces are, may be gathered from the care with which they treasure up and hand down the tradition of every spot where, at any distant period, clay has been found within a serviceable distance. It is the want of this knowledge which causes the innumerable failures they meet with in their attempts to sink wells, and forms the principal source of discouragement to the further extension of this form of irrigation. If wells are ever to be built by the State, it is absolutely necessary that some cheap means should be devised for ascertaining what the sub-soil strata are, before any well is commenced, and there is no way in which professional aid could more profitably be given to native efforts. An instance of what is of constant occurrence all over the Province, was furnished by Rája Shambhu Narain Singh, who was encouraged by the success of some neighbouring villagers to attempt the construction of wells on his own estate. They probably had the advantage of some old tradition, and hit the clay; but he failed to do so, and his money was thrown away, with the effect of making him give up the project of investing a very large sum in this form of improvement. There is little reason to doubt that, if he had known how to take preliminary borings, he would have found mota for as many wells as he could wish for or afford to construct.

11. Another case in which this knowledge is very frequently wanted, is when a thin mota has given way in consequence of the enlargement of the hollow beneath by an unusual demand on the water supply. In a very large number of instances, a second mota can be found within a short distance of the first, and the continuation of the cylinder will restore the well to its original usefulness. But in the absence of the necessary knowledge, the well is given up, and all the money and labour which has been spent on it is wasted.

12. Though the importance of finding a mota was not unknown, it appears to have been very much undervalued before the commencement of the present experiments, and its exact meaning was perhaps not quite clearly understood. The common impression appears to have been that it was wanted because it covered a spring which would not otherwise be found; but this, as has been stated, is a mistake. If its real use had been known, we should not have had the numerous wells resting in pure sand at Moradabad, or the wells which Captain

Clibborn saw on the Gházípur farm, all of which rest on sand, and are therefore next to useless, though there is plenty of mota in the immediate neighbourhood. It is safe to say that, if Government had then undertaken a large scheme of compulsory well construction, a very considerable proportion of the wells made would have been failures for the want of clear ideas on this point.

13. When the subject was first taken up by Government, the implement used for taking borings was an auger, which was both expensive in use and liable to get out of order. In sand it was nearly useless. Mr. Wilson has introduced, and is continually modifying and bringing to greater perfection, a sand pump, which it is believed was first introduced into this country for the attempted artesian well at Umballa. With this he is already able to make trial borings to as great a depth as is likely to be required, at a total cost of Rs. 5 for each boring.

14. There are many cases in which it appears possible that wells may be constructed under conditions which native well sinkers would think hopeless. The first of these is where there is so great a distance between the water level and the clay mota, that the continuation of the brick cylinder to the latter would be unremunerative. The only use of the cylinder is as a reservoir to hold water, and if its contents are sufficient; that is to say, if it is prolonged far enough below the external water level to allow for loss of head by work, and the play of the buckets, there is no use in continuing it any further, and the additional masonry used to bring it on to the clay is, except to make it stable, so much money thrown away. It has now been found that the same stability can be secured by making an impervious cylinder of the size only that is required for a water cistern, and continuing it down and through the clay by an iron tube, which will cost only a small fraction of the expense of a masonry cylinder to the same depth, and answer quite as well. The diameter, material and construction of tube to be used have been the subject of numerous experiments by Mr. Wilson; and some of his conclusions are given in the accompanying note. How great a saving might be effected by this plan of sinking, may be gathered from a comparison of the table of estimated cost given by Captain Clibborn on page 14 of his report, with that given by Mr. Wilson in section 47 of his. Captain Clibborn estimates that an 8½ feet diameter well, sunk 60 feet to the water surface, and therefore with a total length of cylinder of about 90 feet, would cost Rs. 1,634. A tube well sunk 130 feet below the water surface, and with a total depth from the ground of 142 feet, or half as much again as that of the cylinder well, is estimated by Mr. Wilson to cost between Rs. 828 and Rs. 888; or little more than half the price of the shorter well.

15. Even more important are the experiments to ascertain whether it may not be possible, by the introduction of a filter bed of coarse gravel, or other permeable but not easily disturbed substance, either at the sides or the bottom, [illegible] the area of percolation, or of discharge in a sandy stratum, without endangering the safety of the well. If this problem is solved, with due regard to expense, and there appears to be no reason to consider it insoluble, there is hardly a place in the Provinces, except where the water level is unusually low, where wells could not be sunk; and it is not too much to estimate that the area that might be protected by them would be doubled.

16. An instance where the deficient knowledge of natives in well sinking has received a valuable addition, may be found in Mr. Bull's patent dredger, which greatly reduces the cost and difficulty of sinking wells through a sandy stratum.

17. It would clearly be inequitable to embark on a scheme of compulsory well construction, on the understanding that the cost of the wells was to be realized from the men on whose land they are constructed, unless there were definite proof that a sufficient return would be realized from the money invested. The first question to be decided was, what would be the cost of wells at different depths and of different sizes. An estimate was given in the note submitted by Mr. Buck in 1877, another is given by Captain Clibborn in his report now under submission, while Mr. Wilson gives an account of the cost of the wells he is building on the Awa estate. The fact appears to be that no general answer is possible; not only are the circumference and depth to water surface insufficient data for a judgment as to what a well will cost; but whether or no a well will

be remunerative, depends to a very great extent on its being adapted to a number of conditions which may vary with every locality.

18. Before any steps can be taken, it must be decided whether any form of masonry well will cost less in the interest to be charged on capital outlay, *plus* an allowance for repairs and the extinction of the capital cost, than *kutcha* wells to irrigate the same area. This, too, is a question to which no general answer can be given. The decision must depend on the peculiar conditions of the locality, and any new tract in which operations are contemplated, may present conditions not hitherto considered. As a rule, there can be little doubt that, even where *kutcha* wells can be made, masonry wells are in the long run the more valuable. Where water is met at a reasonable distance, and there are no unusual engineering difficulties, Captain Clibborn considers that a return of Rs. 2 per acre will be sufficient to pay for the cost of a pucka well, even on the expensive scale of construction which he contemplates, and there are not many places where an acre can be watered from a *kutcha* well for the same expense. There are besides several advantages in a well which has not to be renewed every or every other year. In the first place, it is ready for use directly after the conclusion of the ordinary period of the rainy season, at a time when *kutcha* wells will not have been made, and its water is available for the sowing of the spring crops. The frequency of the failure of the later rains makes this a point of very great importance. In the second place, even if water is not wanted for the cold weather sowings, the construction of *kutcha* wells takes up labour at a time when it is most urgently wanted in the fields. In the third place, the *kharif* crops can be saved, if irrigation is wanted, from a masonry well; and finally, there is this very great advantage, that a *kutcha* well is nearly always useless in a season of drought, at the very time when water is most needed.

19. There are, however, cases where masonry wells, are only preferable to *kutcha* wells in times of drought, and others where they have no decided superiority even then. An instance of the first class of conditions may be found in the sandy plateau on which the majority of the Moradabad wells have been made. *Kutcha* wells can be built there at a very trifling cost, and are only used to irrigate expensive crops, such as sugar-cane which are not sown on the same field in two consecutive years. Besides their cheapness, they have the further advantage that they can be moved every year to the place they are required to irrigate. On the other hand, owing to the looseness of the soil, they could not be dug if a drought caused a considerable fall in the water level; and masonry wells, though they could hardly be expected to pay in ordinary years, would be invaluable as a protection against famine. Moreover, it is worth considering whether wells, like canals, by raising the standard of cultivation, may not eventually create the conditions of their own remunerativeness.

20. If I correctly understand the conditions of well irrigation in the neighbourhood of Farukhabad, they present a case where, under no circumstances, would a masonry well have the advantage. The water surface, which is at a depth of about 35 feet, and would therefore make a deep and expensive cylinder necessary, is reached through a continuous stratum, of such a firmness, that it will stand without support for a long series of years. I am told by Captain Clibborn that he observed similar conditions in the neighbourhood of the State wells at Cawnpore. They are certainly not common, but in places which are fortunate in having a firm sub-soil to a sufficient depth below the water surface, the wells can be easily dug out a few feet deeper to meet any abnormal sinking in the water, and the expense of building masonry wells would be as much thrown away for times of drought, as for ordinary seasons.

21. A point much discussed when this subject was taken up in 1877, was whether big wells or small paid best. It was then generally thought obvious that, as the cost of a well did not increase in the same ratio with the number of buckets it could accommodate, the bigger a well was the better it would pay. But it is now seen that this is only one of a good many factors in the problem. As was pointed out by Mr. Buck, the loss of water by evaporation and absorption along a long watercourse, might more than extinguish the advantage of the greater cheapness, per bucket, in the construction of the well. Captain Clibborn has made careful enquiries on this point, and finds that this

loss on ordinary soils amounts to two cubic feet per foot run of watercourse in the day, and is so great, that it would pay to add Rs. 300 to the cost of a four-lift well, in order to save the water. Mr. Bull, the proprietor of the patent dredger, who has had very great experience, is of the opinion, that the smaller the wells are, the better they pay; and would reduce the diameter of all to 3 feet, or even less, if it were found possible to build them smaller. Neighbouring districts will be found, where it is the practice to build large wells in one, and smaller in another, and it is probable that the choice in each case has been decided by the wants of the locality. Even for the same number of buckets, very different sized diameters may be required, as the size of the buckets varies from $1\frac{1}{2}$ to more than $7\frac{1}{2}$ cubic feet, being generally determined by the quality of cattle in general use, and the style of irrigation.

22. Not only the diameter, but the depth of the cistern that will be required, the thickness of the steining, whether the well should be made impervious and fed from beneath, or composed of dry laid bricks, and supplied by percolation through the sides, are all questions in which the answer depends on a number of conditions which vary everywhere; and the selection of the kind of well that will prove remunerative, requires an amount of special knowledge which cannot be expected, except in a man who has devoted some time to the study.

23. The want of men who have the requisite qualifications is not the only difficulty which would meet Government, if it attempted a large scheme of compulsory well making. The cost and difficulty of supervision form an obstacle which it is almost more difficult to overcome. The experience of works undertaken by Government agency, as quoted by Captain Clibborn, shows that 27 per cent. on the cost of the work should be allowed for establishment. Wells would be scattered over a large area of country, and would require constant inspection, to provide against the fraud of the contractors who must be employed. It is probable that the cost of supervision would bear a higher proportion to the cost of work in the case of wells, than where the expense is concentrated on a smaller area. Then there would be the contractors' profits, a not inconsiderable item, to be allowed for and finally there would be the loss, not only of the supervision which a private man could give without cost, and with the best chance of its being efficient, but of the wood and private labour which he can contribute much more cheaply than it could be obtained by Government, as in many cases it would be the mere utilization of resources which would otherwise have lain idle. It is perhaps not too much to say that a well, constructed by the State compulsorily, and without the hearty co-operation of the villagers, would cost twice as much as a well equally good, but made by a private person. The conclusions arrived at in the enclosed reports would seem to show that only under favourable circumstances can wells, constructed at the rates there specified, prove remunerative. But there is a constant sliding ratio between cost and profit. As the water surface becomes deeper the area that can be irrigated by the same labour becomes smaller, and there is a constantly diminishing return to a constantly increasing expense. By leaving the construction of wells to private individuals, not only is the remuneration under favourable circumstances increased, but the area over which it will prove remunerative at all is largely extended.

24. When all these considerations are borne in mind, less surprise will be felt at the unwillingness of the zamíndárs, both at Moradabad and at Cawnpore to render themselves responsible for the cost of the wells before any had been constructed. They knew the difficulties which were to be encountered, of which only a dim presentiment, if any, existed in the minds of the Government officers employed; and it is not too much to say that even, now, when it is far better informed than it was then, if Government were to take any large scheme of compulsory well construction, it would almost certainly be doomed to failure.

25. The advantages of well irrigation are too well recognized to require being described at length. The wells already in existence provide for 57·8 per cent. of the whole irrigated area; whereas canals only water 24 per cent., and tanks, ponds, rivers and all other sources 24·2 per cent. In ordinary years it doubles the produce, and in times of drought it is usually sufficient to carry the people through one season of failure of the rains. The distance to which the

water level falls after one such failure is a subject on which the information is defective, but such enquiries as have been made, would seem to show that it was usually not more than 5 or 6 feet, and this is what Mr. Wilson allows for in building the cylinders for the wells in his charge. Rae Bareli is one of the districts in which well protection is most general. After the almost total failure of the rains in the northern tahsíl in 1877, the wells still contained a sufficient supply to save a good spring harvest. Hardly any cultivators came to the relief works, and no relief would have been wanted throughout the cold season, if rain in January had not thrown the agricultural labourers out of work. A second and almost as complete a failure of the rains occurred in 1880, and in that year, when the necessity for labour at the wells continued all through the cold weather, an excellent spring harvest was saved, entirely sown and supported on well water, and no class in the community felt the want of Government relief. The failure of the late rains which serve for the *rabi* sowings, is far more frequent than a complete drought, and in those cases wells enable a spring crop to be sown, which may be kept alive, either by further irrigation; or by the following winter showers. Without wells it is then impossible to raise any spring crop at all.

26. Without going into the very doubtful question of the relative fertilizing powers of canal and well water, it is clear that there are large tracts in these Provinces which are already partly protected by wells. To introduce a canal there would be to sacrifice existing advantages, and to be at the expense of providing a protection for the whole which was only wanted for a part. In such tracts, the whole area would be much more cheaply protected by them than by the introduction of a canal.

27. Another advantage in wells, which can hardly be over-estimated, is the following: It is not necessary to maintain any expensive establishment for the regulation of the water supply, or the collection of dues. Not to dwell on the evils of Government interference with the minute private affairs of its subjects, the financial advantage is obvious. The receipts from canals must pay not only interest on the capital expended, but the cost of establishment. If the same capital outlay per acre were made on canals and on wells, the latter would be cheaper than the former by nearly the whole cost of annual supervision. Supposing that supervision cost 5 per cent., and interest on capital were reckoned at the same figure, it would be as cheap to spend Rs. 100 on wells as Rs. 50 on canals. If equal sums are spent, the difference goes to the pocket of the cultivator, instead of being lost in a purely unproductive expenditure.

28. In his note on the condition of the Awa peasantry, in which Mr. Crooke sums up the experience he had gained during his management of that estate, he urges more than once, that there is no greater practical benefit that a landlord can confer on his tenantry than the extension of well irrigation; and this is a point on which I believe difference of opinion to be nearly impossible.

29. In spite of the recognized benefits, the extension of well construction is as slow now as it was five years ago. It may even be doubted whether the number of new wells is sufficient to supply the loss of those that fall in, or otherwise become useless from year to year.

Before a remedy can be applied, it is necessary to know the causes. In its final report to Government, on the proposed Bill in 1878, the Board of Revenue expressed its opinion, that the main obstacle to well construction was the absence of capital. A second, and perhaps even more fatal obstacle, is the want of knowledge. A third may perhaps be found in the principle which governs assessments on land irrigated from wells.

30. The first obstacle is dealt with by the Takávi Act; but the experience of many years has shown that, whatever simplification in procedure may be adopted, it fails utterly to effect its purpose, and it may be held to be wrong in principle. If the object is worth an effort, and of this there can be little doubt, it is worth while to enquire whether a totally different system, to any adopted hitherto, would not be found more efficient. The first objection to the present system is the tedious enquiry which must be made before any advance can be sanctioned. This appears to be quite superfluous, as no previous enquiry can secure that the money is properly spent. The proper principle appears to be, to attach some small penalty to the failure to spend the money on

the object for which it was advanced. The applicant should specify the field on which he proposed to build his well, and the time within which it would be completed. His work would be liable to occasional inspection, and it might be provided by law, instead of being made a subject for specific agreement, that, if he failed to carry out his engagement, the whole sum advanced, *plus* compound interest, at, say, 10 per cent., might be levied at once by any of the processes allowed for the recovery of arrears of land revenue. A mild penalty of this kind would probably be the most effective means of ensuring that the money was properly spent; and if exacted in one case, would operate as a deterrent in others.

31. Another objection to the system now in force is, that the whole sum must be drawn at once, directly the advance is sanctioned, and interest must be paid on it from the commencement of the undertaking. This makes the loan unnecessarily expensive to the cultivator, who may not be in a position to borrow the whole sum at once, and may prefer to take only so much as he may require as the work progresses. This difficulty might, I think, be obviated by the adoption of a plan recommended by Mr. Webb, the zamíndár of Baraut in Meerut. There appears to be no reason why, when sanctioning an advance, the Collector should not allow the applicant to open a running account at the Treasury, the whole advance to be taken out not to exceed the total amount sanctioned, interest being charged only on such sums as had actually been drawn, and the zamíndár being at liberty to repay so much of the advance as he had taken whenever he found it convenient to do so. The Treasury officer would certify to the Collector the amount of interest due twice a year, once at the first *kharíf kíst*, and again at the first *rabi kist*, and such interest would be added to the Government Revenue. The Collector's order and the Treasury books would be sufficient proof of the advance of any sum, and there would be no need of either bond or registration. At the end of the time within which the applicant had engaged to build his well the account would be closed. If it were found that the money had been misapplied, the whole sum with the penalty would be recovered at once. No great harm will have been done even if occasional instances of perversion escaped the Collector's vigilance. With an officer who took any interest in his work such cases would be very few. There would be no danger of the loss of the money, as, being intended for the improvement of the estate, the loan might fairly be given the priority over other encumbrances.

32. A further advantage from this system would be that the zamíndár would only draw just as much as would be required to make the well. It is impossible that he should be able to estimate this correctly beforehand, and as advances are now made, he not only pays interest on money before he wants it, but very often on money which he finds afterwards that he does not want at all.

33. The question of repayment cannot be considered separately from the question of assessment. There seems to be two alternative principles that might be adopted. The first is to consider the land as the sole property of the zamíndár, and him solely responsible for its improvement. In that case he would be required to repay the principal sum advanced, as well as interest on it till the date of repayment. The terms for repayment, which appear to me to be most appropriate, are those which I believe are used in the Land Improvement Act for Ireland. Annual payments fixed in such a way that the pricipal and interest should be extinguished after a long term of years. Tables could be drawn out showing what percentage on the principal would extinguish that, *plus* interest at say 5 per cent. within given periods. If this principle is adopted, I venture to urge that Government has no equitable claim to any of the advantages which may arise from the investment. It is only as part proprietor that it can advance any such claim, and to assert that, besides the ordinary interest on its loan, which is only to be made on terms which secure it from all pecuniary loss, it has a further title to a share in the enhanced rents, is to claim a right with no corresponding risks or duties. It is in fact to put itself into exactly the same position as it reprobates in the case of worthless landlords, and it should be remembered that besides losing nothing on the money it advances, it will reap the greatest indirect benefits in the stability of its land revenue in the increased prosperity of the people, their increased capacity for indirect taxa-

tion, and their security against famine. If this is admitted, the Madras rule that "wells are exempt from assessment" should be adopted. Believing as I do in the extreme short-sightedness of any policy that offers discouragement to well sinking, I would accept this rule without modification, but if any objection were raised, I would urge that the land protected by the well should be assessed at dry rates for,at any rate, the settlement succeeding the date of its construction. The present rule which leaves it to the Settlement Officer to decide whether the landlord has had enough profit to recoup his original outlay appears to me to be open to many objections, and to operate as a distinct discouragement to well building. In the first place it virtually puts the owner of the well at the mercy of the Settlement Officer, and it is impossible for him to feel any security that his case will be properly considered. His apprehensions, moreover, are not unreasonable, as it is most unlikely that a Settlement Officer should be able to form a correct judgment in the matter. In the second place no one can have read much of the literature of well making without being convinced that it is only under the most favorable circumstances that the enhanced rents secured by a well give as great a profit on the cost of construction as the ordinary market rate of interest for money. As the principal is not extinguished in ordinary investments, but co-exists undiminished with the interest that is paid on it, it cannot be considered that the principal investment on a well has been recovered unless the returns have been higher than the ordinary market rate of interest. Supposing this to be 12 per cent. (for the rate of the native market should be taken not the rate at which Government can afford to lend), the Settlement Officer should not decide that the principal had been recovered until the excess annual profit exceeding 12 per cent amounted to a sum equal to the original investment. It may be doubted whether this would ever be the case, and even then no regard would have been paid to the initial risk. The class of investments should be taken as a whole, and failures reckoned with successes before it would be just to apply the rule. I am therefore of the opinion that the principle recognized in these Provinces should be abandoned, not only because it is unintelligible and distrusted, but still more because it is unfair and inapplicable to the circumstances of the case.

34. The second way of dealing with the recovery of advances for wells would be if the State regarded itself as a joint proprietor in the soil, and jointly liable for the risks, and entitled to the benefits of all investments made for its improvement. The logical action on this premise would be for the State to assess half the profits on every well immediately it was constructed and add them to the land revenue, recovering half the original outlay, with interest on outstanding balances till date of repayment. If the borrower preferred to pay half the original outlay at once, all claims on that account would be extinguished and the State would look as he does, to the enhanced rents for profit on its investment. As it might be inconvenient to make an immediate assessment, a fixed rate of interest by the State might be levied in lieu of its share of the rents till the next settlement.

35. The alternative plans would then be these ;—

(I) The whole outlay to be considered as an ordinary debt, in which case the well should be exempted from assessment.

(2) Half the outlay to be considered as an ordinary debt, in which case the well would be liable to assessment. The assessment profits to be commuted for interest on the State's half of the outlay till the next assessment only.

The main difference between the two plans would be that in the second the State would share both risk and profit. It might be found at the ensuing assessment that the value of the well has greatly diminished, and in that case the State would lose ; or it might be found that the enhanced rents represented much more than the 5 per cent, or whatever was considered proper interest on the original outlay, or in that case there would be a corresponding profit.

36. Either system appears to be fair; the second may seem a little complicated, but I believe that it would have a chance of being popular, and it at any rate avoids the settlement difficulty. In either case the accounts would be made up, and final arrangements made after the running account for con-

struction had been finally closed. It would then be seen exactly what the well, *plus* interest during the time of construction, had cost.

37. Two main obstacles, the want of capital, and the inappropriate rules for assessment having been dealt with, the third, the want of knowledge, remains to be considered. The chief ways in which this may be profitably applied have been touched on in the earlier part of this note. They are—

(1) The selection of sites. This is a point on which both Natives and Europeans are at present liable to fatal and wasteful mistakes.

(2) The repair of old wells which have fallen in, and which only require a little engineering knowledge for their re-construction.

(3) The decision as to the best form and size of well. On this point the local knowledge of natives is generally sufficient, but the judgment of European officers not specially versed in well sinking will probably be mistaken.

(4) To overcome mechanical difficulties which are beyond the knowledge or appliances of villagers.

(5) The suggestion of more effective or cheaper forms of well than are known to native science.

38. The chief additions that have already been made to native methods are:—

1. The sand pump for taking borings;
2. Mr. Bull's dredger;
3. The tube well for places where the mota is found, but at a great depth;
4. The percolation wells, for places where no mota can be found;

and as the art has only recently been made the subject of systematic study, there is every reason to hope that even more important improvements may be discovered. The possibilities of percolation wells are still under experiment, which may lead to their almost indefinite development. In this branch native art has stopped short at a very early period of its growth, and though it deals admirably and exhaustively with a small number of well understood conditions, it is unable to cope with circumstances which have remained outside its range, and is baffled by difficulties which are not insurmountable to more original workers.

39. In order to make our knowledge available, and extend it further, it is necessary to maintain a small staff especially devoted to this work. It cannot be expected that it will be possessed by the ordinary District Engineer, who in fact, is generally as little versed in practical well building as any other layman, and until he has made it a special study, has less to teach than to learn from the village well-maker. The staff should consist of one or two Europeans, with a sufficient number of native assistants. The European officers could travel from district to district as their advice was required by Collectors, and would besides be employed in developing practical experiments on a small scale at the expense of Government. The native subordinates would have direct charge of the experiments while the European Engineers were away, or might be lent to Collectors to give instructions where wells were to be sunk by them or by private individuals. The number of applications for assistance which I receive now is more than Mr. Wilson can possibly comply with. If it were known that it were generally available, such applications would almost certainly increase in frequency. If, as I believe a very great stimulus could be given to private well-sinking by more reasonable terms for pecuniary assistance, and the knowledge that engineering aid was obtainable as well, a considerable staff might be employed to the very great benefit both of Government and of the people. The application of professional knowledge would be infinitely easier and cheaper than that of professional supervision. By showing how one well could be made, the construction of a thousand in the same neighbourhood might be rendered possible. The boring for sites could be done by the subordinate staff, and would ordinarily cost as few days as the completion of the well would take months or even years.

40. In connection with a permanent well establishment, Government might maintain a small store of the appliances for well-sinking, such as various

kinds of boring tools, dredgers, and perhaps diving dresses, as well as supply iron tubing if it were wanted, for tube wells.

41. The general conclusions then that are to be drawn from the lessons of the last few years are that of the three requisites for well building: (1), capital; (2), labor and supervision; (3), knowledge; the first can be supplied far more cheaply by the State than by any villager, the second more cheaply by the villager than by the State, and that for the third the co-operation of the State and the villager is required. I have endeavoured to suggest how these conditions may be best met, that is, by the adoption of a new system of *takavi* advances better fitted to the wants of the people, by a revision of the present rule for assessment on improvements, and by the maintenance of a small Engineering staff for the double purpose of investigation and advice. I have not considered this to be the place for detailed proposals for immediate action, but it might be reasonably hoped that if Government would accept these principles, or any modification of them which discussion might recommend, and publish them for the general information of District Officers, and the people, with a distinct assurance of the extreme importance it attaches to this form of agricultural improvement, a strong impulse might be given to the extension of well irrigation, and that instead of retrogressing, as the ruined remains of wells in many districts would lead us to fear was the case, or at the best standing still, both the science and the practice might receive an immediate development.

42. It has, I hope, been made sufficiently clear that no large scheme of compulsory well building can be recommended for the present. But the Court of Wards in both Provinces offer a field where immediate action is possible, and for every reason advisable. When so great a benefit both to the people and to the estate, as well as indirectly to Government, can be secured, it seems unreasonable to be at a loss how to dispose of the accumulated saving of a minority. Wells should be sunk wherever they are possible on Court of Wards Estates, and the only reason, probably, why this has not been done hitherto, is that the Managers feel themselves to be too little acquainted with practical well building to trust themselves to embark on the enterprise without the help of advice that can be depended on. This difficulty can only be overcome by the appointment of an Engineer whose sole business would be to learn the art, and communicate his knowledge and occasional supervision to the estates. If he worked, for the first at least, under Mr. Wilson, he would be able, to refer to him in cases of difficulty, and acquire in a comparatively short time the knowledge accumulated in years of painful experiment. This is the more to be desired, as if something of this kind is not done, the whole of this valuable experience will be lost when Mr. Wilson, either goes on furlough, or reverts, as it is probable that he eventually must, to the regular line of the Irrigation Department.

43. As further experience is acquired and an adequate establishment is formed, many of the objections which are now fatal to the direct construction of wells by the State may be removed, and it may become a question at some future time whether if land owners refuse terms which are really liberal and decline to protect their estates, Government may not build wells for them and charge them the cost. The want of a trained staff makes this for the present impossible, and until capital were offered to them on reasonable terms by the State, it would be unjust to compel them to pay for the costly supervision of Government officers.

44. There are two points which I have not thought necessary to deal with at length. The first is the distinction between wells as ordinary investments of capital, and as protective works in times of drought. There are large tracts where it is probable that wells might not be remunerative in normal years, though they would prove of the very greatest benefit when the rains were insufficient. It is important to recognize the distinction, but as zamíndárs are not likely to build, against bad seasons only, wells that would not always be financially remunerative, and as Government has not been recommended, for the present at least, to undertake compulsory construction, it is not likely that any but the former class of wells will be made.

45. The second point is far more difficult, and may require immediate discussion. It is whether the zamíndárs require greater facilities for raising rents, or the cultivators better protection for improvements than is given them by the existing law. It is likely that we should be in a better position for forming a judgment when the other obstacles to the application of capital (either borrowed from the State, or belonging to the agriculturist) to permanent improvements have been removed.

46. My acknowledgments are due to Captain Clibborn for the industry which enabled him within a comparatively short time to put together what is probably the largest collection in existence of data for forming a judgment on the probable areas that can be covered by wells of various dimensions, the depth of water required by different crops, the relative cost and efficiency of all the forms of lift in use, and a number of other points on which a clear understanding must be arrived before the practical problem of well sinking can be dealt with successfully.

The Department still has the advantage of Mr. Wilson's services, and it is unnecessary that I should say how highly I value his assistance.

The combined reports contain a mass of information which I hope may be of help to any one who attempts to sink wells in these Provinces in future.

Extracts from Captain Clibborn's Report.

THE SUPPLY OF WATER AVAILABLE FOR IRRIGATION FROM WELLS.

The water-bearing strata.

12. The sub-soil water supply in the Gogra-Ganges Doáb is, as far as is known, inexhaustible, and nearly everywhere it is at a reasonable distance from the ground surface, but irrigation decreases in a marked manner when the depth to water surface exceeds 60 feet. The water-bearing stratum as a rule is sand, which in most instances is overlaid at varying distances from the ground surface by a bed of clay, indurated sand, or kunkur, called variously "mota," "matbarowa," or "nagasan."

Indurated sand and kunkur beds local.

13. The existence of the indurated sand and kunkur beds is obviously due to local action since the Doáb was first formed; they are met with in but a few isolated localities, and have little bearing on the general question.

The mota.

14. Far different is the case with the clay bed or mota. Where it occurs, wells are always possible, and there are few Zemindars or Assamies in any village who cannot point out with accuracy the site and depth of the layer.

When deposited.

15. The mota was deposited at the period of the formation of the Doáb, and in conjunction with the sand strata, was probably the result of action similar to that which now produces clay beds in the khadirs of deltaic rivers.

Not universal.

16. The mota is not universal; its general distribution is shown in *Plate* III., and there are only a few isolated villages even in the best districts in which it is found everywhere.

General distribution

17. Referring to *Plate* III., it will be noticed that the mota is not known at all in those tracts directly underlying the hills, and gradually increases in occurrence as the slope of country decreases, it is, however, much more prevalent in the Ganges-Jumna Doáb than in the Ganges-Gogra Doáb.

All clay not mota.

18. The term mota is not applied to all clay strata, but only to those either underlying or directly overlying sand containing water; there are often many such strata of varying thickness and at different depths.

Situation known to cultivators.

19. Canals are only a recent introduction compared with wells, which in many districts have been the only means of raising high class crops for a naturally stable community. The accurate knowledge which villagers generally possess of the position of the mota is not, therefore, to be wondered at. It is not universal as might be supposed, but when a cultivator asserts his knowledge it may generally be accepted.

From experience.

20. Their information is of course derived from experience gained in excavating for wells, which have either proved failures, or have been filled up or broken long since. In many cases the

memory of the former well has been lost, and I have come across several instances in which new wells have struck on old and long forgotten ones, the sites having been chosen on a tradition of the existence of the môta.

It is curious to note that although the môta may be scarce in a village, if it exists at all the inhabited site will be found on or near it, so placed for obvious reasons, and perhaps the môta may have had more influence on the selection of the sites for great native towns than it is generally given credit for. Amrôha and Bareilly may be instanced.

Sub-soil sections.

21. Sections A to G (*Fig.* 1, *Plate* I.) illustrate various conditions of sub-soil found in the Doáb; they might be indefinitely multiplied, as the clay, sand and water occupy every possible relative position.

Spring wells.

22. Leaving out of the question for the present wells which receive a supply from percolation, we will consider the case of what are usually termed spring ("Bom") wells, which should be sunk so as to have the curb or lower ring firmly embedded in the môta, thereby (if a masonry well) shutting out from direct entry all water overlying it. Now the generally accepted theory regarding the use of the môta for water supply is that it acts as an artesian basin, and that the supply entering the well through an orifice which is bored in the clay is a veritable spring,* caused by the pressure of water from the collecting area of the basin.

Artesian action unlikely.

23. The facts which are alleged to support this theory are *first*, that until the môta is reached the water supply is easily exhausted. This is contradicted by experience. *Secondly*, that when the hole is bored into the môta a copious supply of water enters the well, often causing danger to the workmen if they do not escape quickly, and sometimes rising above the mouth. But the artesian theory pre-supposes the comparative continuity of the môta, which is at variance with the universal testimony of cultivators, and the facts alleged are easily explained on other grounds, *vide* paras. 26-30. It will also be shown that artesian action is quite incompatable with the strata of the Doáb.

Sub-soil water contours desirable.

24. Although the ground surface of these Provinces has been thoroughly surveyed, and numerous cross sections taken of the ground levels, unfortunately there has been but little systematic attempt to contour the sub-soil water surface, for which, in conjunction with the ground surface levels, we possess unrivalled facilities in the numerous wells, and it is certainly desirable that in future surveys the sub-soil water and the position of the môta should be measured and recorded in a similar manner to the ground surface.

The curve usually shown by a Doáb Cross Section.

25. *Plate* IV. shows the sub-soil water and ground surfaces on a section taken across the Deoband Doáb along the Shamli road, and may be taken as a type. The water surface is at its highest in the centre of the Doáb, and gradually falls in a rapidly increasing slope as it nears the rivers on both sides. The longitudinal slope is one corresponding in some degree to that of the country, and over the whole area in which the so-called spring wells exist; it does not exceed 1 to 2 feet per mile. There is abundant evidence that the water from the high land drains into the rivers on each side at a slope of about 1 in 100, or 50 feet per mile, (it varies according to the nature of the stratum,) and even if the môta were uniformly continuous and regularly overlaid the water bearing strata, (which it does not,) it is evident that there could be very slight, if any, artesian action. A type section of the môta as it really occurs is shown in *Fig* 2, *Plate* I.

†Mr. Beresford's theory of supply.

26. The following theory, advanced by Mr. J. S. Beresford, Executive Engineer, Irrigation Department, appears to offer a true solution of the action which takes place.

It is admitted that in new wells when the hole through the môta is first made a certain quantity of sand is forced up into the well with the water; but after a short time this emission of sand ceases ,and if the môta is a good one (3 to 5 feet thick of hard clay) no sinking of the well takes place. A hollow in the sand

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* Such wells are termed spring in the Tables to distinguish them from percolation wells.

† *Vide* Appendix I.

beneath must, therefore, be formed, and Mr. Beresford assumes that it is of the form (C) shown in *Fig.* 3, *Plate* I., and that the môta merely acts as a platform to support the well over this hollow in the sand, which gives a surface large enough to discharge a supply corresponding to the head given.

The "Head."

27. The head is the difference of level between the water inside and outside the well, for when water is drawn from a well, the surface reduces more or less rapidly according to the quantity drawn out and the strength of the supply, and at length a point is reached when the water vacuum is just sufficient to draw in a supply equal to the quantity taken out. This is the mean head.

It naturally varies a good deal over the Doáb, and can be found for any of the experimental wells by deducting the figures in column 67 from those in column 66, Table A.

Artificial imitation of the môta.

28. This theory is well supported by facts familiar to Engineers experienced in laying foundations below water surface on sand, where these consist of a platform resembling the môta. If any flaws exist, after a slight primary emission of sand, nothing but clear water is discharged, and no damage to the foundation occurs, provided the platform is thick and strong enough to act as a beam over the hollow in the sand below. The size of the hollow will be modified by two conditions:—

1. The head, which regulates the quantity of discharge.
2. The comparative fineness of the sand, which regulates the rate of discharge.

The coarser the sand the smaller will be the hollow. Perhaps the best idea of the area required to admit of the delivery of a given quantity of water in a given time may be obtained if we represent the spaces between the particles of sand by the holes in fine wire gauze of varying gauges. Coarse netting will require a smaller area to admit of a given discharge than fine netting.

Action of land springs.

29. Similar action may be observed by any one curious enough to examine the *true springs* when the sub-soil water escapes at the junction of the bangar and khadir. On the banks of our large rivers the khadir from A to D will usually be covered with a clay deposit over sand, and the springs burst out at A, *Fig.* 4, *Plate* I., and flow into swamps between A and D, or to the river direct. A sort of cup or hollow is formed, *see* B, in which the sand bubbles up with the force of the spring, but when the area of the surface of the hollow is large enough to discharge the water supply, nothing but the very finest sand is carried away.

Result of drawing water from a well resting on fine sand.

30. If a well rests on sand alone when water is drawn, abstraction of sand takes place from below, and the well being a heavy body sinks into the hollow. The effect of drawing water from a well in pure sand is to drain an inverted cone, the height of which is represented by the depth of the well below water surface, the steepness of the sides varying directly with the fineness of the sand stratum, *Fig.* 5, *Plate* I.

It will be seen that the content of the cone increases with the depth of the well below the percolation level.

The water nearest the well is first drawn into it, and passing vertically down close outside, draws the sand with it into the well, and if the process is continued long enough, the sand will eventually rise into the well until nearly level with the water outside *

Wells possible in very coarse sand or gravel.

31. The results described will only occur when the quantity of water, drawn from a well is greater than the surface exposed, *i. e.*, the area of the bottom of well can deliver. There are wells on the margins of the Bundelkhand lakes which give an ample supply from fine gravel, and which correspond in every point with the example above described, except that the intervals between the particles are greater.

Wells in fine sand possible but expensive.

32. There is no difficulty in designing a well which would work successfully in pure sand of any fineness, it is only necessary to make it large enough; but the expense in the strata usually met with in the Doáb would be enormous, and as far as practical irrigation is concerned it is out of the question.

* *Vide* Moradabad well experiment.

Wells resting on pure sand are constantly used for drinking purposes without any injury to their stability.

Advantage of the resistance sand offers to flow of water.

33. For the *ordinary cylinder* well it is therefore evident that the *existence of the môta is a necessity for its success** as an irrigating medium, and it is worth noting that but for this very resistance which sand offers to the passage of water, irrigation wells would practically be impossible in the Doáb, for the sub-soil supply would drain away to the lowest point; its contour would be a nearly level line between great rivers, and the depth to water on the watershed, which is now the least at the tablelands, would be a maximum.

Variation in quantity of supply.

34. There are great variations in the quantity of water capable of being drawn from wells close together and apparently similar in all respects, but the explanation is simple enough when we remember that the area of the môta must have a similar effect to an increase in the depth of the well in enlarging the diameter, and consequently the content of the drainage area (*vide Fig.* 6, *Plate* I).

Percolation wells when used.

35. Percolation wells are used under the following conditions :—

(*a*). When the môta does not exist.

(*b*). When it does exist but is at such a depth below water surface that it is too expensive or too difficult for the people, with their existing means to reach it.

(*c*). When wells resting on the môta become injured from various causes.

(*d*). When they pay better than môta wells. Water enters a percolation well by filtration from the sand, either through crevices in the wall of the well, or through a grass or twig lining, which admits the water while holding the sand back. Such wells are generally found in the khadirs and lowlying lands, were recent diluvial action has washed away the former strata, replacing them by nearly pure sand. On the outskirts of the town of Jalalpur, (Shahjahanpur District,) there is a curious instance of this action. For miles round, the Ramganga, which is a great wanderer, has cut away the old strata and the môta is unknown, except where a kunkur stratum exists in a small patch of 16 acres in extent, which is crowded with no less than 14 kucha wells, some of them 100 years old—all worked with Rátis, a class of lift not much used elsewhere in the pargana. Percolation wells are also extensively scattered over the districts lying under the hills, where, as before noted, the môta is rarely found, and as (in common with the khadir) such lands require little water compared with the more southern districts, there appears to exist a sort of balance of power regarding the facilities for irrigation in the various tracts of the Doáb.

With reference to the four conditions under which percolation wells are used, *Case* (*a*) is self-evident; *Case* (*d*) will be dealt with when the cost of irrigation is considered.

Case (*b*) occurs—

1*st*. In villages, most parts of which possess a good môta easily obtainable, but certain other areas have the môta either at a greater depth or overlaid with quicksand, and the people, accustomed as a rule to dig wells with facility, magnify to themselves the difficulties to be met with in these isolated areas, which, in less favored villages, would be considered serviceable.

2*nd*. When the môta is at such a depth that the Capital outlay would leave no margin for profit.

3*rd*. In areas where the môta is overlaid with sand formerly dry, in which kucha "Bom" wells were the rule, but where now, from a rise in water level, the sand has become saturated, and the people are unable to reach the môta simply because they cannot

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* Natural or artificial.

dig through the wet sand. In the 1st and 3rd cases the advantage of Government interference is obvious, advice and regulated advances would be invaluable.

Case (*c*) occurs—

1st. When the môta is thin. If the well is overworked the supply of water will increase, but so will the hollow under the clay, and eventually becoming to large for the thickness of the môta, the well drops through and is practically ruined. This occurs frequently in *famine years*, when good wells are strained to the utmost. Fortunately there is often a second layer some distance below, and were advice and assistance afforded, many pitiable examples of wasted capital could again be made profitable.

Cultivators are frequently well aware of this danger, and will refuse to allow a second *churrus* to be used, although apparently the supply in the well is ample.

2nd. When the well gets broken below, and the owner is afraid to clear it out and re-open the môta. These cases are quite remediable in most instances, but often are beyond the powers of the owners.

3rd. When through carelessness the well is allowed to get filled with débris and a small supply only filters through. This is scarcely a case of enforced percolation, and occurs mostly in those canal-irrigated villages, when the water surface has been so much raised that such a well will suffice for the irrigation of a small plot of opium or garden produce.* In cases like this it would appear advantageous to reserve the canal supply for less favored localities.

4th. When the sub-soil water falls below the môta. This does not invariably result in the well becoming percolation. Often as before mentioned a second môta exists, and if it can be reached the well may be underpinned, and a fresh supply obtained from the lower layer, for its stability is in no way endangered as it rests on the môta above. If, however, no lower mota exists, or if it is at a great distance, the cultivator can only dig a hole in the sand below, line it with grass and obtain a small and intermittent supply, the end is generally the destruction of the well, as the mota is gradually undermined, from the abstraction of the sand by the bucket, and it has also lost the support given by the water formerly below it.

Sources of supply.

36. It is somewhat difficult to understand how the rain water, which naturally must be the main source of the sub-soil supply, finds its way below the surface. Experiments made after heavy falls on plateaus show that the depth to which water penetrates directly into the soil is not great; it varies from a few inches to as many feet according to the nature and level of the surface, and from the sub-soil water contours we see that the rivers even in heavy flood can have little or no effect.† Practically what we want to determine is the source of the supply in the higher levels, *i.e.* AA, of any Doáb cross section, *Fig.* 7, as these must be nearest the source, the lower levels clearly being the result of slow drainage towards the rivers on either side. That this drainage is very slow is both certain and fortunate; certain, because we know that the level in wells even in years of excessive drought falls a few feet only compared with the great difference of level which exists between the surface of the water at the centre and the edges of the Doáb; for instance, in the section of the Deoband Doáb before referred to, the difference of level is 16 feet in a distance of 1½ miles, which is a comparatively flat slope, but we have no record of any fall in wells near this approaching 16 feet. The resistance to drainage, is fortunate

* Cultivators in canal villages often keep up a sort of home farm round the well to employ their cattle on and opium is a favorite crop, as it requires frequent and thin waterings.

† In the Deoband Doáb the sub-soil contour is 5 feet higher in the centre than the maximum flood level in the rivers on either side, and higher up every Doáb the excess is much greater.

as without it the contour would assume the direction of the dotted line C C, (*Fig*, 7, *Plate* I.,) which in many districts would be fatal to the interests of well irrigation. That the rainfall does not filter evenly down from the whole surface exposed may be accepted as evident, but there are great variations in the nature of soils, and any cursory inspection of a map will show the watershed intersected with jhils and hollows, the majority of which undoubtedly have clay beds, but in many the soil is more or less porous.

Sources local.

37. This assumption of local and isolated filter beds is supported by the fact that the rise of water in wells is most marked in some villages, while there is scarcely any yearly variation in others, and in all the water usually resumes its normal level by the end of the cold weather.

Bhognipur well.

38. A good example of the effect of the water in tanks on wells, is found in the Bhognipur village, Cawnpore District, the plan of which (*Plate* VII.) shows a marked variation in depth according to the positions of the wells with reference to the various village tanks.

Normal level.

39. It has been noted that the sub-soil water will practically stand at a slope of 1 in 100, but it must be remembered that this is when it has an outlet, even though the quantity discharged may be small; if no escape is possible and the supply is cut off, the surface must assume a much flatter slope in time.

Water surface high in sandy tracts.

40. Accepting this theory of local sources of supply, we ought to find a high surface level in sandy tracts indifferently supplied with the mota; and the Hasanpur pargana of the Moradabad District is a good example, as there the water level is found at 10 to 15 feet from the surface.

Supply from hill rainfall small.

41. The rivers taking their rise from springs near the hills and the Terai streams carry off a fair share of the rainfall which has been absorbed by the hills. The nearer tracts may be partly fed by the hill rainfall, but it is difficult to imagine the great length of the Doáb to be supplied from such a source; it indeed appears impossible, when we remember the way in which the Doáb is cut up by deep streams often heading the drainage.

Enquiry into local sources needed.

42. The Doáb rainfall must, therefore, be credited with the natural supply of sub-soil water above the mean level of streams, and an enquiry is much to be desired into the local sources of supply, the amount of water held in suspension, and the curves which it assumes under different conditions.

Artificial sources of supply.

43. The artificial supply is obtained mainly from canals, it is, however, local. Permanent sections of the canals are rapidly silt-lined, which forms a good watertight medium, and great attention has for some years been given to fixing gradients which will avoid either errosion or heavy deposits. When percolation occurs, the distance is limited by the abrupt slope which the water assumes, and the amount by the fact that canals are usually carried along the watershed where the sub-soil surface is highest, *see Fig.* 8, *Plate* I. and *Plates* V. and VI.

The Agra Canal.

44. The Agra Canal affords a good example of this action; the water surface has been raised in a gradually decreasing amount as the distance from the canal increases, and at an average distance of half a mile the influence is unfelt.

The local supply from Canals compared with rainfall small.

45. That the influence of the canal in raising sub-soil level is small compared with rainfall is well shown by a section, *Plate* VI., prepared by Mr. W. Willcocks, Executive Engineer, in 1879, which was a year of excessive rainfall, while 1877, also shown, was a year of drought, in which the canal was constantly run with a full supply. The section was taken along the Meerut and Ghaziabad road, which runs nearly parallel to the canal and drainage lines, and is therefore no guide, unfortunately, to the transverse slope of the sub-soil water surface.

Swamps how formed.

46. Swamps are formed by percolation from canals when the level of the ground surface intercepts the line of water slope, and also when the slope is flattened by an intercepting bed of

clay, in both instances puddling the bed would be a more efficient remedy than drainage, which increases the quantity of the water percolated, *Fig.* 9, *Plate* I.

Abnormal fall in water surface a great injury to masonry wells.

47. Drought, as might be expected, has a marked influence on the sub-soil water level in tracts of extended well irrigation when there is no artificial supply.

In some parts of the Muttra District the fall in water surface amounts to from 15 to 16 feet during the last five years, and it has injured a number of wells, as in some instances the water has fallen below the mota.

There is a possibility that the marked and, as far as irrigation wells are concerned, destructive fall of water surface in the Muttra District, has been partially caused by over drainage in the Aligarh District. A glance at the Map will show that the parts of the Aligarh District which have been most effectually drained, were probably the local collecting areas which kept up the sub-soil surface in the tracts now suffering in Muttra, where there are comparatively few jhils, and the fall occurred just about the period at which the drainage system was perfected.

A satisfactory explanation of this, and other interesting matters relating to the sub-soil supply, can only be obtained by carefully observed sub-soil water contours, and the subject of a complete Map of the North-West and Oudh water levels has been brought to the notice of Col. Forbes, the Chief Engineer for Irrigation, and has received his approval as far as the preliminary arrangements are concerned.

How repaired in Muttra.

48. The Assamies have repaired some wells in an ingenious manner by underpinning the masonry with a wooden or a grass lining. An interesting example of this is No. 6618, village Bheema, pargana Mahaban, *Fig.* 10, *Plate* I.

Two-lift well, old. Water surface has fallen 12 feet during last 5 years. For 4 years the well was kept at work with a grass lining, last year a wooden lining was put in. This well cost Rs. 400, and though built with lime, is now showing signs of giving way. The present supply is percolating through the sides of wooden lining or *kothi*.

Where most observable.

49. The following accounts of the abnormal permanent fall of sub-soil water level were supplied by Assamis in the field, and in all cases the fall had caused injury to the wells—

District.	Pargana.	Village.	Fall in feet.
Aligarh, ...	Hathras, ...	Sasni, ...	6
"	"	Hathras, ...	4
"	Iglas,...	Iglas, ...	6 to 8
Muttra, ...	Saadabad, ...	Munsia, ...	6
"	Mahaban, ...	Mirhouli, ...	a few feet.
"	"	Raya, ...	15
Shahjahanpur, ...	Pawaine, ...	Dharmangatpur, ...	5
Unao, ...	Unao, ...	Unao, ...	a few feet.

Bundelkhand supply.

50. In Bundelkhand the sub-soil is not uniform as in the Doáb, the mota is unknown, and supply varies greatly according to locality, both in quantity and depth below the surface of the ground.

Soils.

51. The soils of Bundelkhand and their characteristics are well known; they consist of "mar," "kabur," "parwa," and "rakar." Mar usually overlies the parwa and rakar, the exposure of the surface of which is supposed to be the result of denudation. In the more northern tracts of Hamirpur the direct rainfall appears to be the source of the sub-soil water supply, which has a better chance of filtering down than in the Doáb, owing to the undulating nature of the country.

No mota.

52. The absence of the mota overlying sand charged with water, deprives Hamirpur of the ample supply generally obtainable in the Doáb. But there are local spots where a very good

supply is obtainable, and nearly all the large villages have a fair area of garden cultivation which is irrigated.

Surface level generally high on village sites.

53. The depth to water surface is usually less on the inhabited sites than in the village "har," or outlying cultivation, (*Fig.* 11, *Plate* II.,) and this is explained by the fact that the villages are always from choice placed on parwa soil. Mar being considered feverish, and rakar bad for cultivation. Denudation of mar, of which parwa is commonly the result, would naturally take place first from the highest points of the general surface of the country; the village will, therefore, usually be on a relatively high point of the sandy or water-bearing strata, and consequently near the water.

Rapid fall in water surface after the rains.

54. Although after the rains and during the cold weather the supply is fairly plentiful, yet in many places by the beginning of the hot season it becomes much reduced, and wells frequently dry up. This appears to be due to the coarser nature of the soil, which permits of purely percolation wells being used, *vide* para. 31, but the water can also assume a much flatter slope to the drainage on either side. Deep wells would appear to be the only remedy, but the point to which they should be sunk must be locally fixed, as the water falls below the beds even of the drainages in many instances.

Rock wells.

55. In the southern parts of Hamirpur rock wells are common, the overlying strata are soft and dry, and the wells are sunk into the solid rock, the water gradually increasing in quantity with the depth. The supply is always precarious, and seems to be derived by percolation from fissures in the apparently solid rock.

Artificial supply from lakes.

56. The Bundelkhand lakes are caused by obstructions placed across the natural drainage outlets, where the slope and conformation of the country is suitable for the formation of reservoirs. Direct irrigation is practised from many of them, but is precarious, being dependent on the previous rainfall. Nor is it practised with that economy which the known limitation of the supply and the cost of artificially raising it should enforce.

The beds of these lakes are porous, often owing to the proximity of the hills, much mixed with gravel, and the supply spreads freely through the strata surrounding the lake, and it is here we find the best well irrigation in Bundelkhand. Even when the lakes dry there often remains hidden under the surface a copious supply which is distributed by the cultivators on the most economical principles.

Owing to the short depths to water surface and the coarse nature of the soil, wells can be cheaply built, and the cost of lifting is small.

Canals from lakes not economical.

57. The question of entirely stopping direct irrigation from these lakes is certainly worthy of consideration. The area capable of being irrigated would *certainly* be much increased from the enforced economy, and it is probable that the sub-soil supply would out-last even two years of drought if the lakes were not reduced by directly drawing water from them.

Increase in number of lakes desirable.

58. Even small lakes scattered over the country would be of the greatest benefit, and the capital saved by the omission of the canals might be devoted to the assistance of the Zemindars in building wells, on which a rate could be charged sufficient to cover the outlay.

No. $\frac{911 N.}{IV.-A.}$, dated Naini Tal, the 21st August, 1883.

From—J. S. MACKINTOSH, Esq., Secy. to the Board of Revenue, N.-W. Provinces, and Oudh.
To—Secretary to Government, N.-W. Provinces and Oudh.

DEPARTMENT IV.-A.
MISCELLANEOUS REVENUE.

Present:
C. P. CARMICHAEL, ESQ., C.S.I.

SIR,—In continuation of this office No. $\frac{703 N.}{IV.-A.}$ dated 21st July last, I am desired to forward, for the perusal of His Honor the Lieutenant-Governor, a copy of the collection of papers on well construction in the North-Western Provinces, received from the Director of Agriculture and Commerce, North-Western Provinces and Oudh. The Board at present cannot

procure more copies of the report, but they understand that more will be available immediately.

2. For the reasons stated in my previous letter, it does not seem necessary to go at length into all the topics discussed by Mr. Benett in his covering letter; but I am desired to offer the following remarks. The three obstacles to the extension of well construction, the Director, in his paragraph 29, states to be—(1) want of capital, (2) want of knowledge, and (3) uncertainty of assessment.

3. With regard to want of capital, the Board have never lost an opportunity, for years past, of laying their views before Government on the subject of takávi; and it would be mere waste of time to reiterate these here. They have also separately addressed Government on the plan referred to in paragraph 34, under which it is proposed that the State is to contribute part of the capital expenditure on improvements—a plan originally suggested by Mr. A. H. Harington. So far as capital lent or provided by the State is concerned, the first thing to be done is to pass a workable Takávi Act, and to draw up workable rules under it. When this has been done, if the Government can arrange to place money at the disposal of the Board, either at a low rate of interest or without interest, for the purpose of constructing wells, the Senior Member has no doubt that much more will be done than has hitherto been accomplished. It cannot, of course, be expected that the Government will take the place of private enterprise throughout the country; but that is no reason why the State should not do all in its power to stimulate well construction.

4. In the matter of the investment of private capital in land improvement, the first and main point is to see that the application of private capital is not hindered by any vicious conditions attached to the tenure of the land. Into this great subject, which has of late years been discussed in connection with the proposals made by the Famine Commission, and latterly in connection with the proposals of Rája Siva Prasád, it is needless to enter here. The principles of assessment are, the Board understand, about to come under formal consideration again, and there would be no advantage in partially forestalling the discussion here.

5. As to want of knowledge, Mr. Carmichael does not quite agree with Mr. Benett's views. The results of the experiments made by the State in Moradabad and Cawnpore, in the construction of wells, show plainly that the people understand their own business very much better than the officers sent to teach it to them. Did any one ever hear of a zamíndár with an unimproved property anxious to spend money upon wells, who was debarred from doing so by want of knowledge how to make them? Of course some wells pay better than others. They may not in all cases be dug in precisely the best sites; but to say that a want of knowledge of how to construct them, checks their construction, appears as unreasonable as it would be to say that the want of knowledge how to make drains checks drainage in England.

6. In regard to the special well establishment proposed by Mr. Benett in his paragraph 39, the Senior Member does not understand why the officials to be placed at the head of it should be necessarily Europeans. Provided competent persons can be got, it would be decidedly better to entrust the work to natives. If the Government sees its way to sanction the proposed establishment as a branch of the local Agricultural Department, it would probably be so far an advantage that, if properly supervised, it might acquire some useful information. Whether or not it would be of any use to the people is much more problematical, and the Senior Member sees no justification in proposing the incurring of the extra expenditure on this ground.

7. In paragraph 42 of his letter, Mr. Benett remarks that the Court of Wards estates offer a field where immediate action is possible. It may be noted here that a large number of estates come under the supervision of the Court in consequence of their being in an embarrassed condition, and in such cases little or no money is available for well construction. There are also some large estates, such as Kantit and Agori Barhar, in the Mirzapur district, which have ample funds, but where, owing to physical difficulties, well construction is

	Rs.	a.	p.
1878-79 ...	18,896	9	3
1879-80 ...	28,826	15	2
1880-81 ...	38,037	14	0

not advisable. The figures given in the margin, which have been taken from Statement VI. of the Court of Wards' reports for the three years indicated, show the expenditure incurred in the construction and repairs of wells, and prove that the subject has not been overlooked. It will continue to receive constant attention.

8. It is almost needless to add that no scheme of compulsory well construction, such as that mooted in paragraph 43 of the Director's letter, appears to the Senior Member to come within the scope of practical discussion.

No. A-1395, dated 27th October 1883, from the Officiating Director of Agriculture and Commerce, North-Western Provinces and Oudh, to the Secretary to Government North-Western Provinces and Oudh.

In reply to your letter No. 2213, dated 20th October 1883, Revenue Department, calling for any information possessed by this Department on the subject of trial borings for wells, I have the honour to refer to this office letter No. I-107A, dated 26th June 1883, to the Secretary, Board of Revenue, North-Western Provinces, forwarding a copy of the report on well construction of Captain Clibborn and Mr. Wilson. In those reports will be found a great deal of very valuable information on the subject of boring and of sinking tubes.

I have further the honour to submit an estimate drawn out by Mr. Wilson of the cost of trial borings, such as apparently the Government of the Punjab refer to.

Estimate for tools required to make trial borings for finding the depth to the clay.

The tools required may be divided into four classes :—

(*a*) The pipes and tools required for sinking them.

(*b*) Driving or loading apparatus, with which to weight the pipes.

(*c*) Tools for withdrawing the pipes when they have been sunk to the required depth.

(*d*) Tools required to remove the sand pumps &c., in case the rope breaks.

It is convenient to estimate for each set separately.

a. Pipes and boring tools.

The pipes &c., in this estimate, are sufficient to bore to a depth of 54 or 55 feet below the level of sub-soil water :—

	Rs.	A.	P.
2″ Gas-pipe with levelled couplings 4 lengths—each about 14 feet, @ Rs. 10	40	0	0
1 Steel shoe for above pipes	18	0	0
1 Cast iron funnel	12	0	0
2 Pairs of tongs for pipes and sockets @ Rs. 5-8, each...	11	0	0
1 Double pulley block, 5″ galvanized	10	0	0
1 Oil feeder	1	0	0
4 Sand pumps, @ Rs. 25-0 each	100	0	0
1 Jumper	10	0	0
1 Round jumper	15	0	0
	217	0	0
Add for carriage of above	43	0	0
Cost of one set of Tools (*a*). Rupees	260	0	0

b. Driving or loading apparatus.

This consists of a heavy cast iron clamp and weights similar to those used in driving Abyssinian tube wells :—

	Rs.	A.	P.
Cost of clamps and weights	50	0	0
Add for carriage from Roorkee	10	0	0
Total cost of tools (*b*). Rupees	60	0	0

c. Tools for withdrawing the pipes :—

	Rs.	A.	P.
2 Screwjacks, @ Rs. 30 each	60	0	0
2 Clamps 3″ long with 6 spare bolts, @ Rs. 15 each ...	30	0	0
* 2 Lengths of 2″ gas pipe, @ Rs. 10 each	20	0	0
	110	0	0
Add for carriage	30	0	0
	140	0	0

d. Tools useful in case of accidents.

The rope may break having the sand pump or jumper at the bottom of the tube; or the piston-rod of the sand pump may break off when the pump is at the bottom of the tube. In either case, the pump or jumper can generally be extracted by means of a suitable extracting tool attached to a pipe $\frac{1}{4}''$ or $\frac{3}{8}''$ in diameter, and of the same length as the boring pipe.

The cost, with carriage, should not exceed Rs. 30. The total cost of a set of each class of tools is as follows:—

	Rs.
a.	260
b.	60
c.	140
d.	30
Rupees ...	490

If a number of borings are to be made in one locality, one set of tools *c.* and *d.* will be sufficient to keep 4 to 6 sets of *a.* and *b.* at work, and this is the most economical way of working, as one mistrí can easily supervise that number of borings.

If 5 sets of pipes and boring tools are obtained, the following will be the total cost:—

		Rs.
(*a*) ...	5 sets, @ Rs. 260 each	1,300
(*b*) ...	5 sets „ „ 60 „	300
(*c*) ...	1 set „ „ 140 „	140
(*d*) ...	1 set „ „ 30 „	30
	Total Rupees	1,770

In this case the cost may be still further diminished by reducing the number of sand pumps. Two pumps are worked at a time in sinking one set of pipes. Four pumps have been estimated for, in order that no delay may occur, in case of any of them requiring repairs. If 5 sets of tools are obtained, an average of 3 pumps will be ample for each set, so that the above estimate may be reduced by the cost of 5 sand pumps @ Rs. 257 or by Rs. 125 (1,770—125=1,645).

Each set of tools will bore to a depth of about 54 feet below the water level, and it is not recommended that borings to a greater depth than this should be made at present; and borings to this depth should only be made in sites suitable for large wells about 8 feet in diameter. In sites suitable for smaller wells, it will generally be sufficient to go to a depth of 40 or 42 feet. If the "môta" is not found without these depths, the pipes should be withdrawn. If the pipes reach clay, they should be sunk 3 or 4 feet into it, and the jumper worked for a short time, in order to ascertain if the bed of clay is hard and thick enough to form a good "môta."

As regards the cost of a boring, this varies so much with the nature of the sub-soil, that a correct estimate cannot be framed. If there is much kankar mixed with the sand, the pipe sinks very slowly; but if the sand is coarse and free from kankar, a pipe may be sunk 40 feet and withdrawn in two days. The borings will probably take from two days to a week, and will cost from Rs. 2 to Rs. 5 for labour and Rs. 5 to Rs. 10 including repairs of tools, cost of ropes &c.

* These two pipes are sufficient, if the depth from the surface of the ground to the level of sub-soil water does not exceed 25 or 26 feet. If it exceeds this, more pipes must be obtained. If the depth is less than 12 feet one pipe will suffice.

No. 2312 of 1883, dated Camp Lucknow, the 31st October 1883, from the Secretary to Government N.-W. Provinces and Oudh, to the Secretary to the Board of Revenue, N.-W. Provinces.

Revenue Department.

I AM directed to acknowledge the receipt of your No. $\frac{911N.}{IV.-A.}$, dated 21st August 1883, submitting, with remarks by the Board, a collection of papers received from the Director of Agriculture and Commerce regarding the construction of wells for irrigation purposes in the North-Western Provinces.

2. The papers comprise :—

(1) A note by Captain Clibborn, Executive Engineer, on the results of the inquiry into the general subject of the construction of wells for which he was specially deputed last year.

(2) A note by Mr. W. J. Wilson, Assistant Engineer, on deputation with the Agricultural Department, on the construction of wells in the Awa estate.

(3) A note on the construction of the Moradabad wells, from their commencement in December 1879, to the end of August 1882.

In forwarding these papers, Mr. Benett has reviewed the origin and results of the action taken by Government in the matter of well construction. It is unnecessary here to go over the same ground; but the out-come of the experiments made in Cawnpore and Moradabad, and also of the inquiries now reported by Captain Clibborn, is to make it clear that well construction by the State on a large scale should not, for the present at any rate, be carried further.

3. The circumstances which led to Captain Clibborn being placed on special duty for the purpose of conducting these inquiries were not at the time placed officially on record, nor has Government been furnished with a copy of the instructions he received. Apparently, however, he was directed to proceed throughout the provinces investigating the subterranean water-supply, the mode of construction and cost of the different kinds of wells he found in various parts, the area irrigated by wells examined by him, and the cost of irrigation from them. The statistics and information collected on these points have been brought together in a series of maps, plates, tables, and appendices which can scarcely fail to be of very great interest from a professional point of view; and I am to request that the acknowledgments of Government may be conveyed to Captain Clibborn for the very complete manner in which he carried out the task entrusted to him.

4. The three great obstacles to well construction are stated by Mr. Benett, in paragraph 29 of his forwarding letter, to be—(1) want of capital, (2) want of knowledge, (3) uncertainty of assessment. In regard to points (1) and (3) it may be observed that the Land Improvement Loans Act of 1883 has just been passed, and that section 11 has an important bearing on the future assessment of improvements made with the aid of loans under that Act. It may be added that the Government of India is understood to contemplate abandoning altogether any attempt to value or assess, in future settlements, profits arising from improvements effected by the people themselves. As to want of knowledge, Mr. Benett, in his paragraphs 37 and 38, has indicated the points in regard to which scientific engineering assistance is required, and the chief additions already made, in the course of the inquiries and experiments instituted under the auspices of his department, to native methods of well-sinking. In paragraph 39 he proposes that a small staff, consisting of one or two Europeans, with a sufficient number of native assistants, should be specially attached to the Department of Agriculture and Commerce for the conduct of further practical experiments by Government, and for supervising and giving advice in well construction by private persons and the managers of Court of Wards' estates. He further suggests that in connection with a permanent well establishment, Government should maintain a small store of the appliances for well-sinking, such as boring tools, dredgers, &c.

5. The Lieutenant-Governor is disposed to regard this proposal favourably; but it requires to be fully worked out in detail before final orders can be passed on it. I am to observe that the kinds of well that may profitably be sunk cannot be very numerous or difficult to ascertain in practice; and that if the people can be shown by borings (the necessary tools for making which might be

let out or sold to them) where to sink their wells, and the character of the sub-soil for which a particular kind of well is suitable, they may generally be left to undertake the actual construction of the wells themselves. It may be advisable to have a special Engineer (available for other purposes also) permanently attached to the department, at the cost of Government, for investigating further the various problems connected with well construction. But should he be unable to comply with all the demands for scientific assistance which may be made on the department, the salaries of any other officials, whether European or native, who may be entertained, should be defrayed from fees to be levied from the Court of Wards' estates and other private persons, for whose benefit they are employed. And the cost of boring tools and any other appliances provided by the department should be met in the same way. If Mr. Benett can work out a definite scheme on these conditions, it may be submitted for the approval of Government.

6. I am to enquire whether the Awa estate contributes any portion of Mr. Wilson's salary in return for the services rendered by him in the construction of wells on the estate, and if not, I am to request that the Board will consider whether some contribution should not be made.

7. In conclusion, I am to suggest that, if a sufficient number of copies be available, a copy of the papers now under remark should be distributed to Commissioners of Divisions and District Officers for information, and also to public libraries and other institutions throughout the provinces, where they may be accessible to those likely to be interested in, or to need information on, the questions discussed.

Letter from the Director, Department of Agriculture and Commerce, North-Western Provinces and Oudh, to the Secretary to Government, North-Western Provinces and Oudh, No. A-1455, dated Cawnpore, 19th November 1883.

In continuation of my letter No. 1395, dated 27th ultimo, I have the honor to add the following remarks :—

The borings referred to by the Punjab Government may be considered under two heads :—

(i) Borings to ascertain the depth from the surface of the ground to the level of sub-soil water and the quality of the water, and (ii) borings to ascertain the nature of the strata below the level of sub-soil water, in order to determine the best description and size of well to build. Borings of the first kind are rarely required in these Provinces, there being very few places in which the depth to sub-soil water is not known with sufficient accuracy. Where the soil is firm enough, and there is much kankar in it, it is generally cheaper to dig an earthen shaft 3 or 4 feet in diameter to the level of sub-soil water, than to start a small boring from the surface of the ground. If, however, the soil is too sandy for such a shaft to stand without support, the Abyssinian tube well may prove very useful for finding the depth to the water, and its quality.

These tube wells, and modifications of them, have been tried in connexion with the well experiments that have been made in this department. They are sunk very rapidly in sandy soil; but are stopped by a stratum of kankar, if it is at all compact.

The estimate which I had the honor to forward to you, referred only to borings of the second kind, which are made below the level of sub-soil water, as the sand pumps will not work unless water is present. The tools are specially designed for boring in the sandy sub-soil which prevails in Bijnor, Moradabad, Bareilly and other districts of these provinces, and will probably prove useful in some parts of the Punjab; but they are not suitable for places where the prevailing soil is clay or clayey loam.

No. 30A., dated the 5th January 1885, from Major D. G. Pitcher, Officiating Director of Agriculture and Commerce, North-Western Provinces and Oudh, to the Chief Secretary to the Government of the North-Western Provinces and Oudh.

In continuation of correspondence ending with this office No. 1136A., dated 8th November last, I have the honor to state that such experience as this Department has had of lending dredgers and boring apparatus for aiding

cultivators in sinking wells, leads to the opinion that great advantage might be found, were Government to place sets of such appliances at the disposal of district officers for lending to cultivators either free or at a moderate rate on hire.

2. The value of dredgers, as saving time and labour, and the value of boring apparatus, as saving money in the quick determination of the proper site for sinking a well, is at once appreciated by cultivators wherever these appliances are seen in operation, but the prime cost is prohibitive to men who have at the most three or four wells to sink.

3. Consequently, unless Government comes forward to place these improvements within reach of the cultivator's means, the latter must wait until capitalists take to investing and letting out dredgers, &c., as is now so largely done with sugar-mills, and copper-pans for sugar boiling.

4. Instances have been heard of where men having, become possessed of a dredger, regularly hire it out along with their skilled labour in working it at a high daily fee; but a second-hand dredger may be purchased for Rs. 70 or Rs. 80, whereas a complete set of boring apparatus would cost about Rs. 500; and it is unlikely that until the great utility of making preliminary borings becomes more widely known, private parties will invest in sets of boring apparatus on the chance of letting out on hire.

5. It may be noted, however, that a certain amount of skilled labour is necessary for satisfactory results, and that wherever dredgers or boring apparatus may be placed for letting out, there should be some one in charge who can superintend operations.

No. $\frac{141}{1-336}$, dated Allahabad, the 22nd January 1885, from J. R. Reid, Esq., Chief Secretary to the Government of the North-Western Provinces and Oudh, to the Secretary to the Government of India, Revenue and Agricultural Department.

With reference to correspondence ending with your No. $\frac{1012}{75-7}$A., dated the 24th November 1884, regarding the extension of well irrigation and the cheapening of wells and lifts, I am directed to forward, for submission to His Excellency the Governor-General in Council, copy of a letter No. 30A., dated the 5th instant, on the subject, from the Director of Agriculture and Commerce, North-Western Provinces and Oudh. I am to observe that the question of the supply of boring tools and dredgers in each district or group of districts was one of the proposals made by the Director of Agriculture and Commerce, North Western Provinces and Oudh, in the 40th paragraph of his letter No. $\frac{T}{107}$ dated the 26th June 1883, bound in the volume of papers on the subject of well irrigation, which has been furnished separately to the Government of India. Steps are now being taken to give practical effect to this suggestion.

Extract paragraphs 3 and 4, of a letter from the Government, North-Western Provinces and Oudh No. 968-1218-, dated the 28th May 1885, to the Government of India.

3. With regard to the question of the well experiments conducted by Mr. Wilson, which is referred to in "paragraph 27, section IV," I am desired to refer you to this office letter No. 2313, dated the 31st October 1883, with which were forwarded papers giving a history of these experiments and their results as far as they had gone. The further results are briefly stated in Appendix II of the Director's report. Their general applicability to other parts of India would seem to depend on local conditions of soil and water supply. Of the two special appliances to which reference is made, boring tools are undoubtedly useful, but their price places them beyond the reach of ordinary persons. In this office letter No. $\frac{141}{1-336}$, dated the 22nd January 1885, an arrangement was advocated by which Government would keep such tools in every district and place them at the disposal of private persons at a moderate rate of hire, and I am to refer you to this correspondence for further particulars on this point. It cannot be said that tubes sunk below the well cylinder will everywhere be efficacious. But when it has been ascertained by boring, that clay with a permanent supply of water can be found at a moderate depth below the cylinder, it is more economical to tap it by letting down a tube than by sinking the cylinder. In the same way the tube may be usefully employed where, owing to injury to the masonry or some other reason, it may be impracticable to sink the cylinder deeper.

4. I am to observe that some additional experience has been gained in connection with the wells constructed by the State in the Moradabad District, which will, it is hoped, be shortly available, when the experiments have been completed and closed; and to add that the history and results of these experiments in well sinking have been published from time to time, to enable those interested in such matters to form an opinion of their general adaptability.

Papers Published by Bombay Government.

No. 2,773 dated Poona, 24th September 1883, from Colonel I. M. Greig, R. E., Superintendent Engineer Central Division; Public Works Department, Bombay.
To the Secretary to Government, Public Works Department, Bombay.

Having received reports from all the Executive Engineers in this Division on the subject of the extention of well irrigation and the cheapening of wells and lifts, as called for in Government Resolution No. 519 C. W.—1,157 of the 25th July 1883, I have the honour to submit the following extracts from the letters received from the different officers who could furnish information :—

The *Executive Engineer*, *Ahmednagar*, writes :—

"I think that the system of building wells in this district with brick or stone *and mortar* is needlessly expensive. In the whole of Sind I do not believe that a single cultivator has a well of anything but dry masonry, and I do not see why the same course should not be adopted here if the wells were invariably built circular in form. The saving in cost would be at least one-half.

"I do not think there is any more effective mode of lifting water, suitable for the use of natives, than the self-emptying 'môte'. It is simple, easily repaired, brings up a good supply of water, and only requires one man and a pair of bullocks. The wells in this district are, as a rule, too deep for the Persian wheel."

The *Executive Engineer*, *Sátára*, reports :—

"I have not had sufficient experience of well irrigation to enable me to offer an opinion on the feasibility of cheapening wells and lifts in this Presidency. The rayats might undoutedly in many cases construct wells on a cheaper system than is done at present. For instance, in this district when a rayat sinks a well he apparently takes no trouble about the amount of water required for the quantity of land to be irrigated, but digs a well of from 30 to 40 feet diameter when probably one of from 10 to 12 feet diameter would be large enough. The actual cost of excavation is very likely of no importance to the rayat, who may have plenty of labour available for the purpose; but when, as in the Tásgaon and Válva Tálukas, where stone is scarce, the rayat has to convey stone at considerable cost from very long distances, it must often happen that a well of unnecessarily large diameter is built for the money that would suffice for the construction of two small ones.

"If District Local Funds in constructing wells would build them of small dimensions wherever feasible, the rayats also might in time perceive the uselessness of constructing unnecessarily large wells; but as you are, no doubt, aware, this department is invariably opposed by native opinion whenever it is proposed to build wells of smaller dimensions than desired by local usage."

The *Executive Engineer Khándesh*, states :—

"I have had no experience in excavating wells by machinery of any kind and having been done by manual labour, and I am, therefore, unable to compare different methods. There are old wells in every part of this district some of which have been made under great difficulties in that the water level is at a great depth from the surface and had to be excavated to a considerable depth through rock, and I consider that natives, are, therefore, capable of making wells anywhere. Motes are general in this district, but I consider that where the water is near the surface, the Persian wheel is more effective, but that the môte is better when the well is deep."

2. The reduction of the diameter of wells seems to me the most practicable way of reducing the cost of construction. A diameter of 10 to 12 feet is generally sufficient; but the rayats, as mentioned by the Executive Engineer, Sátára, sometimes excavate their wells with diameters of 30 or 40 feet under the mistaken impression that they thus increase the supply of water. In other words, they spend three or four times as much money as is needed for the well.

3. As noticed by the Executive Engineer, Ahmednagar, cheaper materials may be used for the steining of wells, particularly if their diameters are small, for with smaller diameters a less massive steining may be used. I have seen flat tiles set in mud used, the tiles being shaped like the voussiors of an arch, and dry stones roughly dressed, as arch stones would give a strong steining for wells. When the lime is of good quality a mixture of stone chips and chunam of the character of concrete which might be built without frame-work would form a strong arch and interior lining for small wells. It would usually be cheap, and could be built without skilled labour.

4. The natives seem able to make wells throughout this Presidency, as wells of natives construction are found everywhere.

5. Bullock power seems as cheap a method of lifting water from wells as could be invented for this country, where the farmer has bullocks available from his farm without much additional cost.

No. 2,610 dated Belgaum, 17th October 1883, from Colonel W. W. Goodfellow, R.E., Superintending Engineer, S. D., Public Works Department, Bombay.
To the Secretary to Government, Public Works Department, Bombay.

Referring to Government Resolution No. 519 C. W.—1157, dated 25th July 1883, I have the honour to submit the following observations in regard to the extension of well irrigation and cheapening of wells and lifts, in so far as the Southern Division of this Presidency is concerned.

2. It is not easy to deal with the subject in a short and readable report, but a careful consideration of the views of the Government of India brings out certain underlying principles which cannot be disregarded in making experiments towards attaining the object in view, namely, an improved and extended system of well irrigation.

3. The soil needs water almost everywhere and there would be more wells if there was less risk (pecuniary) in that source of supply.

4. Wells are required by the owners of plots of rich garden land, and, as a rule, are excavated after propitiating a rural deity or consulting some village seer who has been known to make a lucky hit or two in pointing out just where water would be found. Capital is sunk and very often to a ruinous extent, the well-sinker being taken deeper and deeper into difficulties, in the hope of avoiding total loss by ultimately reaching a water-bearing stratum, often too deep to afford a remunerative source of supply.

5. One sad example of this kind deters many an agricultural speculator and the cause of well irrigation suffers, owing undoubtedly to ignorance.

6. The chief objects the Government of India desire to see placed in front of all experiments in well irrigation have been very concisely stated. It is asked (1) if Engineering science can under any circumstances enable natives to make wells in a cheaper manner than they can now make them without referrence to the actual cost of excavation (for willing hands will invariably in their own interests work in a cheaper manner than any others). I am of opinion that Engineering science might come to the aid of natives by plainly indicating where wells should not be opened.

Many districts are now intersected by roads and railways constructed in accordance with duly recorded longitudinal sections showing land levels, and on much sections might at a moderate outlay be accurately recorded the *water* level as well showing depth of spring levels below the surface, and such information if again transferred to all village maps would save land owners and well-sinkers from much of the disappointment and loss they now experience.

7. The next question (2) is as to whether Engineering science can enable natives to make wells in places in which they cannot now make them. I would observe that here increased expenditure and sinking of capital run counter to pre-conceived notions of profit entertained by land-owners, who as a rule reject unhesitatingly what *may* be done at a cost, say, of one hundred rupees for what *can* be done for anything less.

8. Under the (3rd) head of enquiry, namely, whether any cheaper or more effective form of lift can be discovered or can be introduced from one part of the country to another, it may be remarked that there can be no question as to the adoption of a more effective form of lift for water, but here again the

natives prefer what they can make and repair in the most remote village to anything better: hence rude "môte," Persian wheel or "soop," which if only moderately effective are perhaps the cheapest and most ancient methods as well as best suited to the people for lifting water for crops under existing conditions of sun and soil.

* * * * * * *

10. In conclusion, I am of opinion that some further extension of well-irrigation might be attained by the means I have briefly noticed, namely, recording depth of water levels or below surface, spring runs on village or Revenue Survey maps, and that something might be done towards cheapening of wells and lifts by affording the natives of this country the benefit of a knowledge (at the expense of the State) of methods of well irrigation adopted by the Chinese and agriculturists in California. Cases in which more skill and more energy have been added to that patient plodding to which the Indian rayat may justly lay claim.

No. 2,463 dated Bombay, 23rd October 1883, from Colonel J. R. Maunsell, R.E., Superintending Engineer Northern Division; Public Works Department.

To the Secretary to Government Public Works Department, Bombay.

With reference to Government Resolution No. 519 C.W.—1157 of 25th July last, I have the honour to forward the following report.

1. Whether Engineering science can enable natives to construct cheaper wells.

In some portions of the Northern Division the wells are too large in diameter and constructed with costly cut stone or else simple holes are dug which after a time have to be abandoned. In water-bearing strata the diameter of the well could be safely reduced to 5 feet and lined with a steining of moulded bricks; in other districts the wells are built square and with the same costly construction, and this form is ill-adapted to permanency. As a rule, wells of small diameter and deeper than the natives generally carry them would be preferable, but the present arrangement of drawing water by leathern bags—the "mote" system—is somewhat against wells of small diameter, and experiments in arrangements which would require less room than the mote system would be advisable to arrive at the best results.

2. Whether Engineering science can enable natives to make wells in places in which they cannot now make them.

2. As a rule natives are quick in selecting sites for their wells, although in many cases failure attends their attempts. Assistance might be afforded by providing boring tools in each district or as a preliminary measure some Norton's tube wells might be driven and on meeting a water-supply they could be withdrawn and the well sunk with greater probability of success. As a rule well irrigation is only practicable if water is within a moderate depth and can be raised at a moderate cost, and these two conditions are only likely to be fulfilled where well-sinking presents no unusual difficulties. Trained Overseers would be of assistance in sinking wells where rock is met with, by means of the modern powerful explosives in lieu of the old blasting by bad gunpowder, and also to assist in cases where the well passing through sand requires scientific appliances to guard against the danger and cost of the sides falling in.

3. Whether any cheaper or more effective form of lift can be provided.

3. There is no doubt room for improvement here, but the problem is not easy of solution; experiments would be desirable to ascertain the best methods for lifting water and full publicity should be given to these. The methods adopted by the natives at present are principally the Persian wheel and the mote. The initial cost of these is considerable and they are not very easy of repair when out of order. It is suggested that the Persian wheel might be adapted to some simple form of chain pump with leather suckers or a light iron endless chain passing up a galvanized iron tube. Experiments might be made with the modern and simple forms of fan pumps and blowers with a view of adapting them for India by reducing and simplifying these parts and so ascertaining the cheapest and most simple gearing for converting the slow rotatory motion of the bullock to the rapid motion of the fan. Both the mote and Persian wheel have so long been in use and are so well understood by natives, however, that any radical change would be no easy matter and could only be introduced gradually and where the advantage of the new arrangement would be of very obvious advantage.

4. In the rice lands of the Northern Division where the average rainfall is some 80 inches per annum and a total failure of the monsoon is rare, well irrigation could not be economically adopted.

5. It is generally for garden ground, surgarcane and vegetables that a system of well irrigation is suitable and more especially in the alluvial and sandy soils of Gujarát. There is perhaps a wide opening for extending such cultivation in such parts as are at present uncultivated or in obtaining a second crop upon rice land which now lies fallow from November till June.

6. The extension of irrigation and the cheapening of wells and lifts would be assisted by a system of tanks; suitable sites being selected for large tanks to maintain and supply smaller ones near villages and towns. The general water level below soil would be raised and maintained throughout a district provided with a system of tanks, and the construction of wells rendered more economical and simpler.

7. It is not improbable that an imaginary fear of their assessment being raised discourages natives from extending well irrigation, and some assistance from Government in the way of advances would probably contribute to foster such irrigation where the soil was suitable.

8. The conditions which a lift should fulfil to render it useful to rayats are:—

(1). It must be cheap and durable and easily repaired by the village artisans.

(2). It should be suitable for depths from 30 to 50 feet and for a variation of 10 feet in level between morning and evening.

(3). It should be capable of being easily fixed and moved from well to well.

(4). The cost for 1,000 gallons, allowing for all charges for interest, depreciation, repairs, &c., should compare favourably with the present môte or Persian wheel lifts. It should be assumed that the lift would be working for 4 to 6 months only during the year and that the rate of interest paid by the rayat would vary from 6 to 12 per cent.

9. The machine which would meet these conditions and be at the same time cheap, effective and simple, has yet to be invented; its production would materially lessen the cost of wells which have now to be constructed of diameters large enough to admit the bulky system of môte and Persian wheel, and a better supply of water would be available from wells of small diameter and carried to a good depth.

10. Although there are in this Division, more especially in the northern districts, a large number of wells, many more would be desirable. In 1878—the year of drought and scarcity—it was noticed that the general water level was not lowered by more than 2 to 3 feet and where wells existed the supply was as a rule sufficient even in that exceptionally bad season. Every additional well is an additional aid when there is insufficient rainfall and if a well was available for every 10 acres over the total area in which well irrigation is financially practicable the effect of drought would be considerably mitigated, for a single watering would in many instances be sufficient to save a crop and to carry it on through a long break in the monsoon.

11. It would not be advisable perhaps for Government to embark on well construction, but a good deal might be done to encourage the natives to build themselves.

12. If a rayat made a "permanent" well and completed the masonry head-works he should not be charged any special assessment on the bags used for drawing water, but until the masonry head-works were completed they should be treated as "temporary" (kutcha) and a charge varying from Rs. 6 to 12 per bag on each bag used for irrigation should be charged; this system was till lately adopted in some districts.

13. It often happens that a rayat cannot command the capital to build a well and complete the head-works in one or two seasons, but with the labour of his family he may be able to supply himself with a well on economical terms provided he distributes the labour over several seasons. He may dig the hole down to water level the first year, and after two years complete the ring and

then carry out the upper work by degrees, or if he has bad seasons to contend against or any special family expenditure he may leave the upper trough, &c., still longer as he can always make a temporary arrangement for working the well. This is the convenient and economical procedure for the poorer rayat, but under the regulations until lately existing he could not draw water from his well while it was in an unfinished state without paying Rs. 6 to 12 per annum for each bag used, and to a man without capital who might take five years over his undertaking this was a serious drawback.

14. The tendency of the rules referred to was to discourage wells made with home labour, and well-building has hitherto been mainly confined to the comparatively few cultivators who could command capital to complete their undertakings within a short time. Every man who makes a well is a benefactor, for independent of the good he does to himself his work assists Government towards providing against famines, and if an auxiliary well system could be organized for the whole of the country where favourable conditions for it exist, the effect would be very beneficial.

15. The exact shape the encouragement should take is a question to be dealt with by the Revenue Department, but I would suggest for consideration some or all of the following concessions:—

(1). That no well which is intended to be permanent should be treated as "kutcha" unless it remains without the masonry ring for more than three years. That is to say a rayat should be able to dig a well and use the water during construction without charge, provided he completes the ring within three years, and a fine might be imposed for any breach of this condition.

(2). That advances for well contruction should be given at the lowest rate of interest practicable without loss to Government, and the repayment should be extended over a long period so as to be made as light as possible. The rules and procedure in regard to these advances should be framed with a view to simplicity and should be fully explained to the rayats.

(3). That a formal guarantee should be given against enhancement of assessment on account of any new well and that steps should be taken to make the people clearly understand that they will enjoy the full benefits of such improvements.

(4). That the protection of any particular area by means of a well should entitle the owner to an extension of his lease for the protected area, or a portion of it, for a reasonable number of years without enhancement of assessment.

Thus if a rayat made a well, say to irrigate one or two fields, he might under the last suggestion be exempted from any enhancement of assessment on those particular fields at the next revision or for ten, twenty or any fixed number of years. This would give a strong inducement in many cases and without something of the kind a rayat within a few years of a revision (which is the case with most of the rayats of the Kaira district) is not likely to expend capital on property of which the assessment may be considerably increased soon after his expenditure. Large increases are not likely, but this requires to be impressed on the mind of the rayat by some guarantee, for he has not derived much confidence in these matters from tradition and experience. I give the above merely as suggestions and I am quite aware that there may be objections to one or all of them.

16. Apart from well irrigation a good deal might be effected in the storage of water for irrigation and village supply by adopting the system freely carried out in Khándesh of bundhárás across the rocky beds of rivers in the Northern Division.

MEMORANDUM.

No, 351 dated Gujarát District, Camp Gadoora, 30th January 1884, from J. H. E. Hart, Esq., C.E., Chief Engineer for Irrigation, Public Works Department, Bombay.
To the Secretary to Government, Public Works Department, Bombay.

With reference to Government Resolution No. 519 C. W.—1157, dated 25th July 1883, the undersigned has the honor to state that the opinions of the Executive Engineers of the Irrigation Department in Gujarát and the Deccan

do not seem to be much in favour of any attempt to afford so-called instruction to the natives, and very little can be done in regard to improving their system of well-construction or their method of raising the water.

2. The natives seem to understand best, and cling most tenaciously to those systems which have been in use in each locality for generations, and any effort by Government officers to introduce a radical change would probably be received with passive resistance and the attempt would doubtless prove a failure.

3. Nevertheless it is perfectly clear that labour-saving improvements which have been accepted by natives themselves elsewhere could with advantage be introduced in various places throughout the country, if some advanced natives could be induced to adopt them, otherwise it does not appear that any advance can be made by the exertions of Government officials.

4. I forward the extracts from reports of Messrs. Palliser. Rebsch and Joyner who alone have entered into the subject in detail.

Mr. Palliser, Executive Engineer for Irrigation Khándesh, opines that :—

" It appears to me decidedly undesirable for Government to undertake the construction of wells all over the country for the purpose of irrigation. In the first place the construction of ordinary wells is perfectly understood by the natives of Khándesh to which province this report is confined. They are necessarily better acquainted with local resources than any Government Engineer can be, and they could certainly carry out the work at a cheaper rate. If wells were constructed by Government, charges for establishment must be proportionately very heavy as the works would be small and very scattered. Where the want of capital hinders the construction of irrigation wells the present system of allowing " Takávi " advances seems to me preferable to direct action by Government. This question is so well understood that I need not further enlarge upon it.

" The Khándesh well is that which is universal in the Deccan, being from twenty to forty feet in depth, except in the Tápti valley where water is not touched sometimes down to a hundred feet in depth. The water is drawn up in the well-known leather bag or 'môte' worked by one or two pairs of bullocks walking down an inclined plane or ramp. Usually there are two môtes to each well, but a good well has four. A good average is I believe an acre and a half of irrigation per môte. Purely irrigation wells are seldom found where the water is more than twenty-five to thirty feet below the surface, as is frequently the case in Khándesh.

" Where the constructors confine their outlay to severe utility I am not aware that technical advice would lead to much saving in first cost of construction of the ordinary well in Khándesh. The work is so well understood and so simple that it is difficult to say where greater economy could be practised. Occasionally no doubt it would be possible to decrease the thickness of the masonry lining, and to introduce a better bond, but the advice of Government officials would not be sought on such matters and might even be suspiciously regarded.

" I have above alluded to the ordinary wells of the country to which the cultivators are accustomed and which are suited to their needs. Undoubtedly a cheaper well of small internal diameter worked by an endless chain and buckets could be devised, but the time has not in my opinion yet arrived for such a revolution in old habits as this would involve. The wells themselves would have to be constructed by Government and I think to do this would be to carry the assistance of the State too far, to say nothing of the unavoidable waste of money such a proceeding would entail.

" Coming to the second point mentiond by Government I do not think much if any thing can be done in Khándesh at all events. Each village has either one or many wells and the spring level is thus known. Where it is less than twenty-five or thirty feet below the surface and the land is suitable for high cultivation, it is not ignorance which prevents the cultivator from digging a well, but want of capital and means. Where the spring level is more than

thirty feet below ground it would not pay to make a well of the ordinary pattern for irrigation purposes alone, and as I have before remarked it does not yet seem practicable to introduce any other pattern.

"As regards the third and last point, improvements on the present system are undoubtedly feasible and desirable. The bullocks walk down an inclined plane, the man sitting on the rope, until the môte reaches the top and empties itself—an improvement by the way on the Northern India plan of having a second man to empty the bag. The bullocks then walk slowly backwards up the ramp, the drive often half dragging them up, until they reach the top where they stand still for the bag to fill when they are started off again. Obviously there is a waste of time and animal power in the slow backward march up the ramp. I have often tried to get rayats to adopt the (I believe) Bengal plan of fastening the well-rope to the yoke by means of a stout pin which could be unslipped immediately the môte was empty. The weight of the bag would pull the man up the ramp and the bullocks could walk up properly to a feeding trough placed near the top, a second pair having taken their place for the next journey down the incline. The saving in time and economy of animal power by such a a plan is obvious, but whether the feeding trough does not commend itself to our thrifty rayat or whether his conservatism is too strong, I have never succeeded in getting the plan adopted.

"The present is the *cheapest* form of lift, and cheapness is the great point to be considered where there is such a general want of captial among agriculturists. A more efficient form of lift could without doubt be devised. There is for instance the chain and bucket pump worked by a single mule on the Khándesh Model Farm which gives the same out-turn of water as two bags lifted by at least four bullocks on the ordinary plan. But the first cost of the plant is from five hundred to a thousand rupees which to the rayat is simply prohibitive. Although the Government Farm well has been working for many years and is admitted by all intelligent natives to be an immense improvement, yet not a single well has been introduced like it elsewhere in the district that I am aware of. I once met at the Farm a man who had travelled some seventy miles to see the things of which he had heard so much—a well-to-do Patel of Sávda one of our largest towns. He made many intelligent enquiries about the working of the well and was much struck with the stream of water induced by the easy walk round of the mule. But on asking and hearing the price of the plant he said 'Sáheb, it is impossible. Our people will never lay out so much money, even if they possessed it.' A difficulty which would be almost insuperable is that of repairs, and there must be a general rise in mechanical knowledge and skill among the village artisans before any improved type of lift can be generally introduced."

Mr. Rebsch, Acting Executive Engineer for Irrigation, Sholápur and Kaládgi reports:—

"The universal form of wells in these districts consists of a large basin 15 to 30 feet square sunk down and into rock which is generally the water-bearing stratum. The springs tapped in the rock have, as a rule a very small discharging capacity and the water in the well never rises above a certain level, determined by the head of water which feeds the spring; in the same well the level varies according to the seasons, being highest during the rains. It is in order to store as large a quantity of water as possible during the time the well is not worked, that the basin is made so large. The necessity of making this large chamber and also because the well has to be sunk into several feet of rock, makes well-sinking a very laborious and expensive operation. Most wells vary in depth from 20 to 40 feet; it is unusual to find them deeper than 40 feet and they are seldom met with less than 20 feet deep. The cost is, as a rule, from Rs. 400 to 800, but this limit is largely exceeded when lining is necessary for the greater part of the well, generally a face wall of dry stone, on the side that the môte is to be worked, is all that is necessary.

"It is impossible to reduce the cost of constructing such a well without at the same time reducing the quantity of water in it available for irrigation.

"Regarding the second question raised, *viz.*, the making of wells in places where they cannot now be made, it may be taken for granted that, as far as the cultivator's means permit, all favourable sites where the wells would tap water at a small depth and where land suitable for irrigation is available have already been utilised and that the extension of well-making would have to be at less favourable sites. The construction of a well of the ordinary pattern would be expensive and it is doubtful if tube wells, which would answer well for drinking purposes, would be able to supply a sufficient quantity of water for the irrigation of an area of land in any way commensurate with the cost incurred. The 'Madras' pattern of water-lift is simple and efficient and by means of it a single bullock can easily lift as much water as two bullocks working on ordinary mote. It consists of a drum, with vertical spindle worked by a bullock yoked to an horizontal lever. Two leather motes of the ordinary pattern are worked by the drum, one ascending full while the other descends empty; the weight of the motes and gear is thus nearly neuteralised and the power of the bullock is spent in raising water alone.

"The bullock works on a level circular track, and by adjusting the length of the lever a small or inferior bullock can work the mote. This form of water-lift is of very simple construction, is in accordance with the usage of the cultivators and can be made by any village carpenter if he has a model in front of him."

Mr. Joyner, Executive Engineer for Irrigation, Belgaum and Dhárwár, reports:—

"The question of utilising the power of the wind for raising water in this country has not, I think, yet had a fair trial. I am aware that it was tried in some water-works in Kolhápur and elsewhere and I think unsuccessfully. But in California, where I think the winds are not so strong or so steady as they often are in the Deccan, one sees simply thousands of little wind-mills all raising water out of wells. For irrigation these would probably need reservoirs and it becomes a question whether the cost of these would prohibit these wind-mill pumps from competing with the bullocks and 'mote.' The pumps and wind-sails are very simple and do not easily get out of order. As their cost is not much it would be a simple matter to buy a few for some of the different Executive Engineers in this Department to experiment with and report on. It is a point in their favour that where the country is hottest and driest (the winds are the most continuous and strongest in such districts, too,) irrigation would be of the most use.

"In the parts of the Deccan which I know and the Southern Marátha Country I do not think it is possible in any way to construct wells for irrigation merely, cheaper than the natives do. They are almost always in rock or murum or hard clay shales, and so rarely lined, the top portions if in soft strata are merely rivetted in stone. In such strata, wells of some size are necessary, as the springs are not often strong enough for irrigation without the aid of a certain amount of storage. It is probable that wells might, much more frequently than they are, be constructed below tanks and canals and so utilise more completely the advantages of such works. In such positions it is probable that wells of a much smaller diameter might be made, similar to European wells and constructed by the help of a curb. In Japan where irrigation is very carefully carried out, small diameter irrigating wells are lined with baked clay rings.

"In China where there is a good deal of irrigation, the chain pump of a very simple construction is very extensively used for lifting water, worked by a pair of bullocks or less frequently by hand; the discharge by this contrivance appears to be very much greater than any 'mote,' though it is not perhaps suitable for great depths. It can be very cheaply made. In both China and Japan almost every farmer in the irrigated lands possesses a little wooden wheel for lifting water a few feet, worked by one man, by the hands or feet, or both, and this is movable and fixed up easily whenever required. By this simple contrivance the irrigable areas are largely increased.

"I think it is only in the cases of deep soft water-bearing soils that modern contrivances such as centrifugal pumps and excavators could cheapen the cost or make possible the construction of wells."

5. The construction of wells by Government must always be more costly than if undertaken by villagers themselves on account of the high charges for establishment and by reason also of the unnecessarily more costly style of work which would be adopted.

6. As to the introduction of new machinery for lifting water, this can only be decided by experiment carefully and honestly conducted for the special purpose. Any amount of theory can be advanced on the subject and makers and patentees will promise sanguinely but fallaciously.

7. I think also that some trial on proper principles and by the proper persons should be made on the efficiency and practicability of applying wind engines.

8. My only doubt on the subject being how to deal with these circular blasts which are so common in the Deccan and which would be I fear fatal to wind-mills.

9. There is also the difficulty as regards the power of wind in its uncertainty and irregularity; large reservoirs to contain a reserve of supply being necessary at all times.

No. 150 C. W.—315 of 1884.

Extract from the Proceedings of Government in the Public Works Department, dated 4th March 1884.

Read again Government Resolution No. 519 C. W.—1157, dated 20th July 1883.

Read letter from the Superintending Engineer, Central Division, No. 2773, dated 24th September 1883.

Read letter from the Superintending Engineer in Sind, No. 2679, dated 5th October 1883.

Read letter from the Superintending Engineer, Southern Division, No. 2610, dated 17th October 1883, with accompaniments, and No. 225, dated 26th January 1884.

Read letter from the Superintending Engineer, Northern Division, No. 2463, dated 23rd October 1883.

Read letter from the Chief Engineer for Irrigation, No. 351, dated 30th January 1884.

RESOLUTION.—In May last, the Government of India drew attention to the desirability of encouraging the extension of well irrigation by reducing the cost of wells and lifts, and building wells in places where now there are none. The opinions of the Chief Engineer for Irrigation and of the Superintending Engineers of Divisions have now been received, and their reports should be printed for circulation to the Department, and to all Revenue Officers, and to the Director of Agriculture.

2. The general conclusion arrived at in these reports seems to be that the existing system of Persian wheels and motes is at present best suited to this country, as the natives are accustomed to it, and the machinery is simple, can be constructed by the villagers themselves at no great cost, and is easily repairable when out of order.

3. Revenue Officers should endeavour to make the villagers understand that the construction of a well can ordinarily be cheapened by limiting its diameter to about 10 feet, or to such dimensions as may be absolutely necessary to work the motes; anything more than this adds largely to the cost without affording any commensurate advantage, as the principal requirement of a well is depth rather than width.

4. The cost can also be reduced by building the well with dry stone masonry.

5. The lift may be improved by fastening the well rope to the yoke by means of a stout pin to be unslipped when the mote is empty, allowing the bullocks to walk freely back up the ramp. Again, the chain and bucket pump, used in the Khándesh Model Farm, can be recommended to those whose means will permit them to incur the extra cost of starting the well, and who can secure sufficient mechanical knowledge to keep the lift in repair. The Madras style of lift, described by Mr. Kebsch, appears to be cheaper and more efficacious than that used in this Presidency. But it is doubtful whether windmills would be serviceable, as supply reservoirs would be needed on account of the uncertainty and occasional violence of the wind.

6. As regards engineering science enabling natives to make wells in places in which they cannot now make them, it is believed that natives generally understand where water is most likely to be met with, and that the main hindrance to well-making is not so much want of science as want of money. The extension of well irrigation would probably be advanced by grants of loans to meet the first cost of the well and lift, and to enable the cultivator to complete his well, and bring it into use in one year; this point may be considered in the Revenue Department. It is understood that, under the orders in force in the Revenue Department, no enhanced assessment is imposed at revision of settlement on account of the construction of wells.

7. No doubt much money has been wasted in digging wells which have turned out to be useless, and the villagers should be encouraged to consult the officers of the Public Works Department before embarking on their enterprise; but a warning against unlikely places would seem to be more required, than mere advice to dig in a probably successful site, where great depth or costly machinery would involve an outlay beyond the means of the village

8. A copy of these papers should be forwarded to the Government of India in the Revenue and Agricultural Department for information, with reference to their letter, dated 14th May 1883.

No. 7, dated Bombay, 9th February 1885, from F. D. Campbell, Esquire, Executive Engineer, on Special Duty; to the Secretary to Government, Public Works Department, Bombay.

With reference to Government Resolution No. 730 C. W. 1624 of 6th November 1884, I have the honor to submit the following report on the result of my investigation on the subject of cheapening the construction of wells for irrigation purposes and on the most economical method of raising water suitable for the purposes of the rayat.

2. The portions of this Presidency in which the enquiries have been made, are those of Gujrát and the Deccan; and as the general features of these two districts vary to a great extent, I propose to deal with each separately.

3. The area comprised by the term Gujrát has been assumed to include all that comparatively low, flat, and rich land lying to the north of the river Damanganga, bounded on the western side generally by the sea and on the east by the Dáng jungles of Khándesh, the Sagbarri and Rajpipla, and again further north by the hilly and wilder portions of the Panch Mahâls and the Mahi Kantha; on the northern boundary lies the Palanpur State.

4. Within this area no hill or rocky ground is met with, except in portions of Káthiáwár and in the north-east corner near Modása; the whole surface of the country consists of recent alluvial soil, and for all practical purposes may be considered quite flat; the southern portion near Surat is 40 feet above sea level, at Baroda it is 120 feet, and at Ahmedabad 160 feet, and the more elevated portions near Godhra and the Panch Mahâls boundary are generally not more than 200 feet above the sea.

5. The superficial strata, to a depth of 100 feet at least, consist uniformly of a sandy loam, varying but little in texture, excepting that, occasionally, a more or less compact bed of kunker nodules may be met with, as well as local layers of fine dry sand, as is usual in alluvial deposits.

6. The depth at which water is found over almost this entire area varies only to a slight extent comparatively, and on an average it will not be greater than 40 feet; in the majority of wells that I have measured, it was between 25 feet and 35 feet. Near Baroda I found the water at 18 to 20 feet below ground level, and at Nadiád about 32 feet, and in the Surat districts 30 to 40 feet. There is, however, a strip of country, between 3 and 5 miles in width, running along both banks of the river Mahi in which the water level is deeper, as might be expected owing to its proximity to the river, which runs at a great depth below the general level of the country, *viz.*, 105 feet, as ascertained from the railway section levels. The depth to the water here is occasionally as much as 90 feet. There are but few wells in this strip, as it is not found remunerative to lift water, as a rule, for cultivation from a greater depth than about 60 feet.

7. The character of the water in most of the wells is hard and in some places almost brackish, but it is generally quite suitable for irrigation, excepting in tracts near the sea and in that part of the Ahmedabad district which lies to

the westward of Sánand; in these portions of the country, owing principally to the increasing saltness of the water, few irrigation wells exist.

8. From enquiries which I made on the spot I learned that the rayats do not experience any difficulty in ascertaining at what depth water will be found on any new site that may be fixed on for sinking a fresh well; those existing in the neighbourhood give them a very good approximation as to this depth, and, should more certain information be required, a trial shaft of small diameter is sunk at an average cost of Rs. 10—seldom exceeding Rs. 15—and this shaft is increased to the full required diameter should the result be satisfactory.

9. With regard to the subject of the size of the well it has been determined by experience that a diameter of 5 feet is the least that, under ordinarily favorable circumstances, will afford a sufficient supply for one "Cos", or bag, worked with a pair of bullocks, the average being about 6 feet, and by a rule of thumb the diameter is increased by about 2 feet for every additional bag that it is proposed to place and work on the well.

10. Mr. Crosthwaite, who was engaged in 1877 to report on the proposed water-supply of the city of Baroda, after making some experiments on wells in the neighbourhood, assumed as the basis of his estimates that a supply of only 15·98 gallons per square foot of bottom area per hour was obtainable from wells in Gujarát soil; but I obtained a far higher discharge in two ordinary cases in which measurements were taken. One well, 15·8 feet in diameter, on which nine bags were working, on being drawn down $10\frac{1}{2}$ feet below normal level gave a supply of 64·8 gallons, or 10·4 cubic feet per hour per square foot of bottom area; and another good well of 5 feet, worked by one bag, gave a constant supply of 103 gallons, or 16·3 cubic feet per square foot on being drawn down 8·1 feet; and these results correspond with the practice and experience of the rayats, mentioned above, in determining the size of these wells.

11. With respect to the depth below normal water level to which wells are usually sunk, I found that the practice varied with the nature and porousness of the material excavated; the process of sinking was always continued as long as the water could be kept under by as many temporarily erected bags or "Cos", and other auxiliary means as there was room to work, and on being overpowered it was accepted that the supply obtainable was sufficient, and the sinking was then stopped. I found from various measurements that this depth is generally 20 feet, and in one case it was 30 feet, but occasionally it is much less.

12. The plan practised by the Gujarát rayat in sinking and building up their wells is the usual one adopted wherever sandy material is met with, *viz.*, a circular excavation is made of such diameter as will provide room for the necessary brick-work lining of $1\frac{1}{2}$ feet in thickness, and is carried down to the water level; a strong wooden curb-ring of the proper dimensions and one foot thick is then laid down at the bottom, and the masonry lining of brick and lime is built up on this curb to a height of 10 feet.

The undersinking and excavation then again proceeds, and the curb with the masonry, which is added to as required, sinks down gradually, and this process is continued as long as the increasing percolation of water can be withdrawn as above described, and the men are able to work.

The completion of the upper portion of the lining is then taken in hand; this portion of the masonry is often "cutcha",—that is, the bricks are set in mud instead of lime, either being used according as the funds available call for economy or otherwise.

13. In accompaniments Nos. 1 and 2, two estimates of the cost of two different kinds of wells are given; they were obtained from an ordinary native village well-sinker, and the rates and prices are those he charges to the rayat; the total depth estimated for is a moderate one of 40 feet, but they may be accepted as being suitable to an ordinary case, and will give a fair idea of the cost of many common irrigation wells in Gujarát.

14. In the neighbourhood of the city of Ahmedabad, of Kaira, and Surat and other large towns, where "potters" are to be found, a very economical plan exists of lining the insides of some of the small cheaper wells, from the very bottom upwards, with thin rings made of segments of baked pottery instead of brick-work these segments are about 4 inches in depth and $1\frac{1}{2}$ in thickness, and four

or five of them make up a circle of 5 feet in diameter. The whole inner surface is protected with a coating of lime plaster, and wells so constructed are found to last as long as fifty years; the cost of such wells is between Rs. 45 and Rs. 60 according to depth and diameter.

15. In the accompaniments marked No. 3 are given plans and estimates of various wells constructed in the Kaira Collectorate, by the Executive Engineer, for village water-supply (drinking); they have been very substantially built and are far more expensive than the class of wells required for irrigation, and they are merely given as an illustration of the cost of some of the best-built ones.

16. Judging from the geological and physical features of the country it does not appear to be possible that any supply of water would be obtained from wells of an artesian nature. Borings have been made at various places with the view of testing this question, *viz.*, at Broach, Navsári and at Surat, but no results whatever have been obtained; the bore at the last place now in progress has reached a depth of 150 feet, being 115 feet below ordinary water-level, but no artesian source of supply has been tapped.

17. The only case in these districts where a supply of water has been obtained under circumstances which might, at first sight, by some be pronounced to be artesian, is that of the pipe now discharging in the bed of the Mahi River which was lately sunk at the time when some work connected with the foundation of the railway bridge piers was in progress. The end of this pipe entered at some depth a highly porous stratum, and the supply of water in it is so constant that a jet or fountain, 6 feet high above the low water-level, is obtained and, according to Mr. Crosthwaite's report, this water will rise in a pipe to 15 feet above that level; but this would still be 90 feet below that of the surface of the country, and would probably correspond with that in the wells not far from the river banks.

18. It has been found occasionally, during the sinking of an ordinary well, that, on reaching the normal water-level and excavating down below it, the percolation into the well was perhaps slight owing to the unusually tight or clayey nature locally of the soil passed through, but that, later on during the progress of the work a much more porous and sandy stratum was suddenly entered, and the water would come in so quickly that the workmen would be obliged to retreat in haste, leaving their tools behind them, and which could never afterwards be recovered; the level to which the water would rise, however, would not be above that of the normal level. A case of this kind occurred in Baroda when deepening the railway well there, and it has also happened in some wells constructed by the Executive Engineer of Kaira. It should be understood, however, that this peculiarity is not confined to wells in Gujarát alone, but may occur in any well sunk in all sorts of material, and has no connection with a true artesian supply, which must necessarily rise to or above the natural surface of the country.

19. Norton's "tube wells" have often been vaguely suggested for irrigation purposes. The tube is not generally more than 2 inches in diameter, and the supply obtained from them is between only 100 and 200 gallons per hour according to the sandiness of the soil; they were designed for obtaining a moderate supply from the beds of sandy streams, with as little delay as possible, where the water lay at a small depth of 15 feet or so, and the material was so loose that the sides of any excavation made would not have stood. As in the case of all pumps they are useless for depth above 25 feet, and from this it will be understood at once that they are not at all adapted for irrigation purposes, even where the soil admits of their being driven down.

20. From the description, given above, of the whole question concerning wells in Gujarát, of the nature of the water-supply and the practice of well-sinking as now carried on by the rayat, it will be seen that there are no peculiar difficulties calling for science in any shape to overcome; and with regard to economy in construction, the rayats are conversant, with, and do make use of, when necessary, a very cheap system of well-making, which it is impossible to improve upon.

21. With respect to the apparatus used for lifting water from wells in Gujarát, the "Cos" or leathern bag of two patterns is everywhere adopted. The "Ramio" is a bag without a spout, and requires a special man to draw it

on to the trough and empty it; the "Soondia" has a spout, and is more self-acting; it empties itself by means of a separate cord fastened to the spout, and attached to the yoke, as is seen everywhere in the Deccan. One pair of bullocks generally is employed for working these bags, and 80 to 90 trips are made in an hour, depending, of course, on the depth; but when a larger quantity of water is required, two pairs are used, working alternately; at the end of each trip the rope is disengaged from the yoke immediately the bag has been emptied, and is run back quickly by hand into the well, refilled, and attached to the the other pair which is standing ready, the first pair in the meanwhile coming up leisurely to the starting point.

22. The size or contents of each bag varies to some extent, and is generally in proportion to the weight of the pair of animals working it. The average discharge of nine that I measured at one well was 2·7 cubic feet and at another it was 3·55 cubic feet, and the quantity of water lifted 47 feet was 223·2 cubic feet per hour, or 1,785·6 cubic feet during the working day of 8 hours. This quantity, however, must vary in every case—depending on the weight and smartness of the animals and on the height the water is raised, but the above may be accepted as a fair working example for that height.

23. I think it right here to point out what appears to me to be an error in a pamphlet, compiled by Mr. W. M. Fletcher for the *Bombay Gazetteer* on "Deccan Agriculture". At page 13 some calculations are given from a report by Colonel Sykes, who states that 198 wine bottles measured 231 quarts, and thus calculates that a pair of bullocks lift 2,931 gallons, or 473 cubic feet in an hour. From the usual size of the wine bottle now in use I make the quantity raised to be 243 cubic feet, and not 473 cubic feet, per hour.

24. From various enquiries made in the district I ascertained that the usual rate of hire of a pair of bullocks, with the driver and the leathern bag, &c., was 12 annas for a day of 8 hours' work; the quantity of water, therefore, that can be raised one foot high per rupee is 111,897 cubic feet.

25. There is a modified form of working the leathern bags—which is, by some, supposed to be an "improved" one—known generally under the name of the "Double Môte"; it consists simply of an arrangement for raising two bags alternately by means of a vertical revolving drum, round which the ropes attached to the bags are wound. The bullocks work the drum by means of a long bar or lever fastened to it, and walk in a circular path till one of the bags is emptied of its contents; they are then made to reverse, and walk in the opposite direction till the other bag has been brought up and emptied. By this arrangement no increased mechanical effect is gained over the direct pull, which is used in the ordinary "Môte". Supposing the length of the lever was twice the diameter of the drum, all other conditions being similar, one bullock might draw up the same bag that two are usually able to do by the direct action; but it would take at least twice the time to do it in, owing to the length of the path being doubled.

26. In practice, however, an animal cannot on a small circular level path exert the same force and to such good effect as it can do on the straight inclined one of the ordinary single môte, which generally has a slope of about 1 in 5; and again, although the animal is more continuously in work in the double machine, it works more vigorously in the ordinary one during the short period it is drawing, and it has often been shown by scientific authorities (see Twisden, para. 16, in the case of work done by a man mounting a ladder) that animal power will always produce the highest mechanical effect when worked, as it were, intermittently—that is, violently for a short period, and assisted by gravity—the time of intervening rest being occupied in regaining the original position: an example of this may be seen in the practice of coal-whippers in England.

27. In Gujarát, where the wells have an average lift of 40 feet, it is almost invariably the custom to unhitch the rope and walk the bullocks up to the starting point, but when this lift is low they are made to "back" up the slope.

28. In the annual report of the Madras Government Farms, Mr. Robertson, of Sydapet, specially alludes to the economy of lifting water by the "Double Môte," and he states in his report "for the years ending 31st March, 1876, paras. 61 and 62,"

that it raised 433 cubic feet per hour with one bullock. It is impossible here to check this amount, but on examining some of the figures given by him in other places the comparison drawn between his and the single môte do not appear to be quite fair; amongst others, in the 60th para. of the above-mentioned report he enters the price of a pair of bullocks set to work the single môte at Rs. 40, showing they were inferior animals, and the contents of the bag they were able to work at 20 gallons, while the price of the one large bullock which worked the double môte was Rs. 53, and the contents of the two bags at 30 gallons each, and with such figures goes on to prove that the cost of raising water by it was one-half that of raising it by the single môte; and in the 186th para. of the same report he again speaks in praise of the machine.

29. The Bombay Government in their Resolution No. 5309, Revenue Department, dated 16th October 1878, on agricultural improvements refer to a letter from Mr. A. Wedderburn commending the "double môte", and they request Mr. Stormont, of the Khándesh Model Farm, to inspect the machine and report accordingly. This he did in his report No. 223 dated 6th December 1878 (extract from which is attached; see accompaniment No. 4), and he states that he did not find it kept in working order either at Sydapet (Madras) or at the Lál Bágh (Bangalore), but that other means for raising water for the land were in use, thus showing that in practice it is not so efficient a machine as would at first sight appear. Mr. Stormont has one erected at the Burgaum Model Farm, Khándesh, but does not use it, as he finds it preferable to work the bags in the ordinary way instead; and I am also informed by Mr. Clerke, Executive Engineer for Irrigation, Poona that a native gentleman there erected one on his farm at Hurupsur near Poona, but has removed it, as he was not satisfied with the results it gave.

30. The other native methods of raising water in this country are the Persian wheel with a chain of earthen pots or tin buckets, the Madras, Picottah, and the "Soop." The two latter are for low lifts, and, not being suitable for wells, will not be further considered.

The Persian wheel as usually constructed consists of a "trundle" or open barrel formed of bars of wood, and is made to revolve by means of rough-cogged wheels; over this barrel is loosely laid an endless chain of two parallel ropes kept apart by a number of short bars like the rungs of a ladder, and to these bars the small earthen pots or tin buckets are attached. Friction between the ropes and the barrel is the only force which prevents the buckets when full, from sliding back down into the well, and for this reason only small buckets can be used, and the quantity of water raised is proportionately small, and very much less than the power exerted by the animal working it is capable of raising. By employing a number of parallel rows of these buckets on a long barrel a larger quantity could be raised, but a simple calculation would show that to utilise fully and, therefore, economically the power of a bullock, the number of rows required would render the barrel heavy and cumbersome, and the oscillation of the different chains of buckets which is always going on, would cause interference and fractures of the buckets, and prevent the successful working of the machine.

31. I have not yet found a Persian wheel which raised anything like the quantity of water it ought to do when worked by bullock power, and I do not consider it a sufficiently perfect machine to be placed in serious competition economically with a môte.

32. A great variety of more or less perfect machine-pumps and water-lifts of European origin and construction have at various times been recommended; the cheaper ones, such as chain pumps, &c., consume too large a proportion of power in friction to work economically, but one known as "Burgess' Bucket Lift" deserves consideration as the best and simplest yet brought forward. It may be shortly described as a perfected Persian wheel, and I have carefully worked and tested it. There is one in constant use at the Sháhibág gardens at Ahmedabad belonging to Mr. Nowrozji; it is designed to lift 6,000 gallons per hour, and marked in the maker's catalogue as size No. 2, and requires a very heavy pair of animals to work it; the tension or pressure produced on the neck was very great, and such that the bullocks could not continue working for long at a time, and required rest at short intervals, and

after making due allowance for these stoppages and other causes I found that the quantity of water actually raised 31 feet did not in practice exceed 2,500 gallons, or 401 cubic feet per hour.

33. The lift cost Rs. 950 to erect in all, and the allowance for interest on capital, annual repairs, and depreciation for machines of this class may be fairly estimated at not less than 12 per cent. or Rs. 114 per annum. Assuming that the hire of the pair of large bullocks for working it was no greater than that mentioned in para. 24, *viz.*, 12 annas per day of 8 hours, and omitting interest charges, the quantity of water raised one foot high per rupee would be 132,597 cubic feet, or an excess of 20,700 cubic feet over that raised by the môte; and for each day an excess of 15,528 cubic feet, and during a working year of 300 days it would amount to 4,657,500 cubic feet raised one foot high, representing a saving against the môte of Rs. 35, but as the charges amounted to Rs. 114, there would be a final deficit of Rs. 79 at the end of the year.

34. I now propose to consider but one more machine, *viz.*, Hartford's Windmill or Californian Pump, which, as the motive power may be said to cost nothing, has been suggested as an economical means of lifting water. A number of trials have been made with it at Surat, Poona, and Kaira, but the results have not been satisfactory. Attached hereto is a copy of a report by Mr. Little, Executive Engineer of Kaira, on the results of a year's working. The machine raised on an average during the month of June, when the monsoon wind is stronger and more steady than usual, 120 cubic feet 28 feet high per day of 24 hours, which is about $\frac{1}{18}$ at most, of what is raised by bullock power in 8 hours for 12 annas, and at this rate the value of the year's work would be Rs. 15. The cost of the machine with fixing at Kaira was Rs. 600, and the interest and working charges as usual at the low rate of 12 per cent. would be Rs. 72, thus showing a deficit of Rs. 57 per annum on this small engine.

35. Whether a large machine would show proportionately better results or not, it is impossible here to state; but it is clear that the windmill, with the amount of wind usually available in this country which will be able to raise a quantity of water equal to that by a pair of bullocks with a bag, would have to be on a very much larger scale, and the usual charges on the capital cost and repairs would amount to a far larger sum than the cost of hiring a pair of bullocks and bag, which, as before stated, is 12 annas a day, and for the 8 months that irrigation is necessary would amount to Rs. 180 per annum.

36. To employ steam as a motive power economically it is necessary to work it on a large scale, and as continuously as possible, but by that means the quantity of water raised would be far in excess of the requirements of the individual rayat and also of that which the ordinary wells could supply, and, therefore, will not be considered here further than to give an example and the results of the experience obtained at Baroda, where a small engine has for some time been used for raising water for the public park. It is not an expensive machine and cost altogether Rs. 5,000. The Superintendent informed me that the fuel and the working expenses alone, without taking into consideration the usual charges for interest &c., &c., made the cost of raising water by it exactly equal to that of raising it by bullocks with the leathern bag; in the accompanying table of the various machines, marked No. 6, the true comparative cost is shown.

37. All the different varieties of water-lifts worthy of notice have now been described and compared, and it appears that for simplicity and economy in results none can surpass the ordinary leathern bag worked by bullocks, and this must necessarily be so in a country where animals as a motive power are so cheap and the machine used is so simple that it produces at least 90 per cent. of the power employed in working it; this is not the case in any other water-lift that has been brought forward as yet.

The Deccan.

38. Under the term Deccan is included all that portion of the Bombay Presidency lying to south of the Sátpuda Hills in Khándesh and to the eastward of the great range of the Western Gháts. The general features of its surface vary greatly; and everywhere may be seen soil, moorum and rock alternating with each other in quick succession; but it is the flatter portion of the

country that must be more particularly considered now with reference to wells, as it is there principally that the soil is of such quality as to make irrigation worth undertaking.

39. The depth of soil generally is nowhere very great, excepting in some of the black-soil plains on the banks of the River Krishna in Sátára, and of the Don in Kaládgi, and a few other localities where the depth may be 40 feet; but it is probable that over more than 95 per cent. of the country the depth will not exceed 10 or 15 feet, and is generally far less. Immediately below the soil lies the "moorum," a porous friable material supposed to be derived from trap rocks; it is loose and soft at the top, but gradually increases in density and hardness the deeper it is worked into, and it is often not easy to determine where it passes into the real basaltic rock, which everywhere underlies it at some depth or other, and which is an exceeding hard, dense, and non-porous material.

40. In well-sinking all the springs of water are, as a rule, found in the lower portions of this moorum formation, and scarcely any will be met with after the solid basaltic rock has been entered, though, of course, an occasional fissure in it may be struck with good fortune by which a good supply of water is obtained, and there are a sufficient number of instances of this having occurred to induce many a well-sinker to continue blasting into the solid rock with the hope that he will ultimately be successful also; but, generally, it is not advisable to continue sinking into basaltic rock with this view if no springs have been previously found.

41. The depth at which water is found in the Deccan usually is not great; in the majority of cases I have noticed over the whole country it is between 20 and 30 feet. In the attached list, marked No. 5, of 31 wells in various villages of the Poona Collectorate only 5 exceed 30 feet in depth, and but one 40 feet, and these may be taken as very fairly representing the usual figures for the Deccan.

42. There are localities such as those in villages in Sávda and Nandurbár, on the banks of the Tápti River, and also in some parts of the Dhárwár Collectorate where the depth exceeds 60 and occasionally 100 feet, but these are exceptions, and the places are well known, and irrigation wells are not, as a rule, attempted there.

43. But, considering the subject in a comprehensive manner, it may be stated that a supply of water will generally be found at an easy depth where there is good soil worth cultivating.

44. The most variable feature, however, of the supply is the natural power of the springs, *viz.*, the quantity to be obtained per square foot of side surface, and on this point there is no rule; it is certainly far less than in Gujrát and consequently, the wells generally have a larger diameter and are from 10 to 12 feet for one bag or mote; it is also not always continuous throughout the year; the springs may be strong and abundant for four months after the rains or till the end of the cold weather, but will quite fail during the hot weather, and the well would be useless for sugarcane or perennial crops.

45. The total cost of each well is much the same as those in Gujarát. Though larger in size, the lining of the inside is not so expensive, as, owing to the hard nature of the material in the lower portions, the walling is only required for the upper to support the earth and soft moorum, and the cost is not high, owing to the cheapness of stone.

46. From the above description it will be seen that the construction of these wells requires no special skill or art; they are simply large excavations of from 10 to 20 feet in diameter carried down about 10 or 15 feet below the point where water is first struck, and the walling or lining of stone and chunam, or occasionally of dry stone, is often built up by the rayat himself.

47. The trough for receiving the water lifted is often a very inexpensive one, being composed of rough slabs of stone laid in clay, and the wood-work of the posts and struts to support the pulley for working the leather bag is generally of undressed timber on which a minimum of carpentering labor has been expended, and the whole arrangement works admirably.

48. In the accompanying tracing a rough sketch of an ordinary Deccan well is given, and I consider it quite suited to the requirements of the rayat and the peculiarities of the country; and I cannot see in what way any radical improvements on it can be suggested, either as to construction or with a view to reduction of cost. I would here mention, however, that I have occasionally come across wells of a rectangular shape, the four side walls being straight. This is not a good one either for stability or economy; the straight wall must be much thicker to support the sides than is necessary in a circular one, and the total length is proportionately greater. I believe the rayat is generally aware of this, but still many mistakes are made, with the result that the straight sides fall in after a few years. I therefore think that whenever opportunities occur for giving advice, they should always be told to adopt the circular pattern.

49. An abstract estimate of the cost of an average well is given, marked No. 7, attached to the sketch, and amounts to Rs. 227, which is, I think, not too expensive, though, no doubt, larger sums are often expended in cut-stone work unnecessarily.

50. The arrangement for lifting the water from the well is invariably the môte, or the leathern bag; it has the spout, and is self-emptying, as described already in the case of the Gujarát "Soondia Cos"; each bag is generally worked by two pairs of small bullocks yoked in front of each other, and often two bags side by side are worked together by one driver, who manages the four pairs of well-trained animals alone, thus economising greatly in the number of men required as compared with the usual practice in Gujarát.

51. The size of the bags generally used is larger than is the case in Gujarát. They contain between 6 and 8 cubic feet each; but as four bullocks are employed, the quantity raised per animal per hour is less owing to the small size of the cattle, and they are also not worked so smartly, and draw up fewer bags in a given time, probably because they are not fed as well as they are in the above-mentioned country, and are generally in poor condition.

52. In bringing this report to a close I would remark that it is often assumed that on working the ordinary môte the power and exertions of the bullocks are not made use of to the best advantage, and that by some other kind of machinery far higher results might be obtained; by means of the following figures it will be seen that such is not the case; in the accompanying statement, marked No. 6, column 5, it is shown that the quantity of water raised by two bullocks in 8 hours, 47 feet high, is 1,785 cubic feet, and this is equivalent to 10,871 pounds raised one foot high per minute. In Molesworth's Engineering Pocket-book it is stated that the number of pounds an ox is capable of raising one foot high per minute is 12,000, and as an ordinary bullock in this country is certainly not more than half the weight of an English ox, and after making due allowance for the friction of the machine, the result shows that the animals were working fully up to the amount that could be expected of them.

53. With reference to the letter from Messrs. Merryweather and Company, alluded to in the correspondence attached to the Government Resolution, and to their offer of making a trial with their sample pumps, I learn on enquiry at their office that they have not any special design ready suited for irrigation purposes here, but that they are willing to work out one if supplied with some description of the machine wanted, and its requirements. I would, therefore, suggest that they may be informed simply that the only conditions imposed will be that the machine should not be on a large scale, but suitable for irrigating about one acre per day, and for lifts of various heights up to 60 feet; and that it should be capable of raising at least 115,000 cubic feet of water one foot high per rupee of cost, including all charges on capital, depreciation and repairs; a machine that cannot do this will not be able to compete with the "môte."

54. For the purpose of making the necessary enquiries connected with the question on the improvements to wells and lifts I have visited a variety of places and conversed with the district officers and many natives who took a great deal of interest in the subject, and have discussed with them each point on which

it is generally supposed that great difficulties exist, and concerning which it has been suggested that improvements should be made; and I trust that in the above report I have dealt sufficiently in detail with the most important of them, and have shown clearly that, taking the country as a whole, these difficulties are not of a serious or unusual nature, and that nothing further can be effected in the way of introducing new or cheaper systems of well construction or of lifts than those which the rayat is already familiar with. He often does practise the greatest economy possible on both these points according to circumstances when there is a necessity for it; and with the numerous examples of the different kinds of construction before him he is always at liberty to choose that which is best suited to his requirements and means.

ACCOMPANIMENT No. 1.

Abstract Estimate of the cost of constructing an ordinary irrigation well with pottery ring lining in Gujarát.—(By a Native well-sinker).

Quantity.	Items of Work.	Rate.			Per.	Amount.		
C. ft.		Rs.	a.	p.	C. ft.	Rs.	a.	p.
600	Excavation and removing earth down to 30 feet depth	3	0	0	100	18	0	0
270	Excavation and removing sand and water down to 40 feet	10	0	0	100	27	0	0
18·8	Tamarind wood curb ring	4	0	0	1	75	0	0
188 Sq. ft.	Ring of brick and clay for 10 feet below water line	22	0	0	100	41	0	0
480	Ring of pottery and chunam above water line	10	0	0	100	48	0	0
480	Filling behind rings	3	0	0	100	14	0	0
	Trough and wood-work for pulleys	50	0	0	1	50	0	0
	Total ...	102	0	0	502	273	0	0

NOTE.—These rates would be greatly reduced when a large portion of work was done by the rayat himself.

ACCOMPANIMENT No. 2.

Abstract Estimate of the cost of constructing an ordinary irrigation well with brick and chunam lining in Gujarát.—(By a Native well-sinker.)

Quantity.	Items of work.	Rate.			Per.	Amount.		
C. ft.		Rs.	a.	p.	C. ft.	Rs.	a.	p.
810	Excavation and lifting down to a depth of 30 feet	3	0	0	100	24	0	0
270	Excavation and lifting sand and water down to 40 feet	10	0	0	100	27	0	0
18·8	Tamarind wood curb ring	4	0	0	1	75	0	0
7520	Brick and chunam lining with sinking ...	34	0	0	100	256	0	0
	Trough and wood work for pulley	50	0	0	1	50	0	0
	Total ...	101	0	0	302	432	0	0

NOTE.—These rates would be greatly reduced when a large portion of the work was done by the rayat himself.

ACCOMPANIMENT No. 6.

Statement showing the economical value of various Machines for raising Water from Wells for Irrigation suitable to the requirements of the Rayat.

Description of Machine.	Price erected.	Interest and depreciation.	Daily working cost.	Quantity of water raised per day of 8 hours.	Height.	Quantity raised one foot high per rupee.	Cost of raising 1,000 cubic feet 1 foot high.	Remarks.
	Rs. a. p.	Rs. a. p.	Rs. a. p.	Cubic feet.	Feet.	Cubic feet.	Pies.	
Single or ordinary "Môte"	......	......	0 12 0	1,786	47	1,11,897	1·71	The rate of hire at 12 annas per diem covers all charges for bags and ropes.
"Double Mote" (Madras)	135 0 0	30 0 0	0 9 0	3,072	20	95,440	2·01	From Mr. Robertson's figures daily cost covers wear of bags and ropes.
Burgess' Bucket-lift	950 0 0	114 0 0	0 12 0	3,208	31	93,598	2·05	Working at Ahmedabad.
Persian Wheel (Bombay)	50 0 0	12 8 0	0 6 0	432	20	20,946	9·31	Near Bombay.
Hartford Windmill Pump	600 0 0	72 0 0	......	120	28	17,342	11·07	Worked at Kaira.
Steam Engines (Baroda)	5,000 0 0	600 0 0	8 8 0	23,114	49	1,07,865	1·79	At Public Park, Baroda.

Note.—The results given are those obtained from machines actually in work except in the case of the Madras Double Môte, for which the figures were obtained from Mr. Robertson's report.

ACCOMPANIMENT No. 6 A.

Statement showing the economical value of various Machines for raising water from Wells for irrigation.—By Mr. Robertson of the Madras Farm.

(Copied from the Saidapet Experimental Farm Manual and Guide by Mr. Robertson.)

Description of Machine.	Height of Lift.	Raised per hour.	Required to water one acre of ground one inch deep.	Men required.	Cattle required.	Cost of Machine and of its erection.	Daily Cost. Manual labor.	Daily Cost. Cattle labor or fuel.	Daily Cost. Interest on Capital and cost of repairs and other charges, charged over 250 days.	Cost of raising 1,000 cubic feet of water.	Cost of raising 1,000 cubic feet of water 1 foot high.
	Feet.	C. Feet.	Hours.	No.	No.	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	A. p.	Pies.
Double Mête ...	20	384	9·45	1	1	135 0 0	0 3 0	0 4 0	0 1 4	2 5	*1·44
Single do. ...	20	256	14·18	1	2	25 0 0	0 3 0	0 8 0	0 0 3	4 11	2·95
Picotta ...	12	290	12·52	3	...	10 0 0	0 9 0	...	0 0 1	3 5	3·42
Ditto ...	5·75	368	9·86	1	...	6 0 0	0 3 0	...	0 0 1	0 11	1·91
Double Bucket Picotta	7·5	560	6·48	2	...	10 0 0	0 6 0	...	0 0 1	1 2	1·87
Archimedian Screw-lift	2	400	9·08	1	...	45 0 0	0 3 0	...	0 0 5	0 11	5·50
Burgess and Keys' Bucket Pump...	22	448	8·10	1	2	380 0 0	0 3 0	0 8 0	0 3 8	3 8	2·00
Steam do.	28	3,840	·95	3	...	5,000 0 0	1 10 0	6 14 0	3 0 0	5 4	2·29
Chain Pump...	12	250	14·52	1	1	500 0 0	0 3 0	0 4 0	0 4 10	5 3	5·25

**Note*.—(By Mr. Campbell). This does not include the charges for annual renewal of leathern bags and ropes; including this it would raise the cost to 2·01 pies.

ACCOMPANIMENT No. 7.

Abstract Estimate of the cost of an ordinary irrigation well in the Deccan.

Quantity.	Items of Work.	Rate.	Per.	Amount.
		Rs. a. p.	C. ft.	Rs. a. p.
2,625	Excavation in soft murum and earth ...	0 12 0	100	19 10 0
785	Do. hard murum	2 0 0	100	15 12 0
785	Do. rock...	6 0 0	100	47 2 0
697	Walling or lining	15 0 0	100	104 8 0
1	Trough	10 0 0	Each.	10 0 0
1	Wooden supports for pulley	10 0 0	Each.	10 0 0
1	Removing water during work	20 0 0	...	20 0 0
	Total ...	...	...	227 0 0